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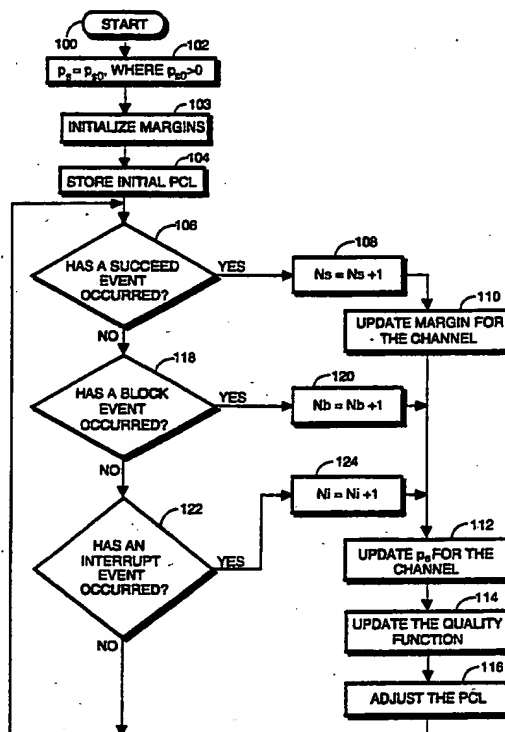
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(54) Title: METHOD AND APPARATUS FOR DYNAMIC CHANNEL ALLOCATION

## (57) Abstract

A base station (21, 22, 23) in a radio communication system (20) comprises a channel allocator (62) for allocating communication channels by accessing a Preferred Channel List (PCL) (64). The PCL ranks channels (116) in accordance with the occurrence of prior events on the channels (112), such as interrupted calls (122), blocked call setup requests (118), and calls successfully completed (106) and in regards to the mean quality margin (110) and the current channel quality (114). The channel allocator (62) allocates (140) the first available channel (128) in the PCL having a free timeslot (132) and with good current channel quality (136).



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**METHOD AND APPARATUS FOR  
DYNAMIC CHANNEL ALLOCATION**

**Field of the Invention**

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This invention relates in general to radio communications, and in particular to channel allocation of radio devices for two-way radio communications.

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**Background of the Invention**

Radio communications involves either one-way (e.g. selective call signalling or paging systems) or two-way communications (cellular, cordless telephone, or digital personal communication systems) over radio waves. Communication takes place on channels, comprising time division multiplexed (TDM) timeslots or frequency division multiplexed (FDM) frequencies, or a combination thereof.

For various radio communications, fixed radio frequency spectrum are assigned. For example, in the United States, the Federal Communications Commission reserves various portions of the radio frequency spectrum to designated communication services. The radio frequency use is therefore limited to assigned services. The radio frequency use is more overtaxed within certain areas where the number of frequencies allocatable for communicating between radio transceivers in a system are severely limited.

As communication between radio transceivers is initiated, the system allocates a channel or channels for communication service therebetween. With the increase in radio communications, such as cellular and cordless telephone usage, the method for allocating channels must allocate channels utilizing the assigned frequencies in a manner to accommodate ever increasing concurrent users.

Signal interference may result from multiple simultaneous usage of the same channel in neighboring geographical areas (co-channel interference) or usage of adjacent channels in the same geographical areas. The resulting interference reduces the level of system service quality. It is therefore a primary concern of the system operator to allocate channels for communication in a manner to allow the greatest efficiency of usage while reducing interference in order to maintain a certain level of service quality.

There are generally two types of channel allocation methods: fixed channel allocation and dynamic channel allocation. Fixed channel allocation methods fix the channel assignments during the entire course of operation. Since the channels are allocated only once, the fixed channel allocation method can be very time intensive and, therefore, have a good chance to provide a high level of channel reuse for any given conditions. Fixed channel allocation methods are simple and may approach being optimal in terms of channel reuse to any given traffic pattern for a given system. But the fixed channel allocation is not adaptive to a changing service environment. Also, to add or remove a base station from the system is cumbersome and fixed channel allocation methods are unable to automatically initialize the channel allocation.

Dynamic channel allocation methods, on the other hand, allocate channels in accordance with a method which is adaptive to traffic and environment changes. Since dynamic channel allocation methods do not assign channels, channels can be used in any area as needed. In addition, most dynamic channel allocation methods can initialize automatically. Unfortunately most of the existing dynamic channel allocation methods are too dynamic to have good performance in terms of channel reuse.

Generally, dynamic channel allocation methods have better performance than fixed channel allocation methods in light and unevenly distributed traffic. However in heavy traffic, typical dynamic channel allocation methods perform worse than fixed channel allocation methods.

Thus, what is needed is a method and apparatus for channel allocation which combines the benefits of fixed channel allocation methods and dynamic channel allocation methods that is adaptive to the slowly changing environment while approaching the maximum system capacity with acceptable service quality for any environment.

#### Summary of the Invention

In carrying out the objects of the present invention in one form, there is provided a method for channel allocation in a radio communication system comprising a plurality of base stations and at least one handset for communicating on a plurality of channels. The method comprises the steps of (a) receiving a request for channel allocation at one of the plurality of base stations from one of the at least one handset, and (b) allocating one of the plurality of channels for the one of the at least one handset to communicate. The one of the plurality of channels is allocated in accordance with a mean margin value of a plurality of measured margins of channel quality of the one of the plurality of channels in relationship to a predetermined threshold channel quality.

In another form, there is provided an alternative method for channel allocation in a radio communication system comprising a plurality of base stations and at least one handset for communicating on a plurality of channels. The alternative method for channel allocation comprises the steps of (a) one of the plurality of base stations receiving a request for channel allocation from

one of the at least one handset, and (b) allocating one of the plurality of channels for the one of the at least one handset to communicate. The one of the at least one channel is allocated in response to determining whether  
5 the one of the plurality of channels is assigned to the one of the plurality of base stations and whether the one of the plurality of base stations is lightly loaded.

#### Brief Description of the Drawing

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FIG. 1 is a diagram of a cordless telephone communication system in accordance with the present invention.

15 FIG. 2 is a diagram of a service area of a multiple base station cordless telephone communication system in accordance with the present invention.

FIG. 3 is a block diagram of a base station in accordance with the present invention.

20 FIG. 4 is a flowchart of the operation of the controller of the base station of FIG. 3 in accordance with the preferred embodiment of the present invention.

FIG. 5 is a flowchart of the operation of the channel allocator of the base station of FIG. 3 in accordance with the preferred embodiment of the present  
25 invention.

FIG. 6 is a block diagram of a cordless telephone handset in accordance with the preferred embodiment of the present invention.

30 FIGS. 7, 8, 9 are flowcharts of the operation of the controller of the handset FIG. 6 in accordance with the preferred embodiment of the present invention.

FIG. 10 is a flowchart of the operation of the call initiation routine of the controller of the handset FIG. 6 in accordance with an alternate embodiment of the present  
35 invention.

FIGs. 11, 12, 13, and 14 are flowcharts of the operation of the channel allocator of the base station of FIG. 3 in accordance with the alternate embodiment of the present invention.

## Detailed Description of the Invention

The present invention is applicable to all forms of  
5 radio communication, such as cellular radio telephone  
systems or cordless telephone systems, which have a need  
to allocate communication channels to users. The  
preferred embodiment of the present invention is described  
herein in reference to a cordless telephone system  
10 operating in accordance with the Digital European Cordless  
Telephone (DECT) specification.

Referring to FIG. 1, a DECT system 20 comprises  
telepoint base stations, such as 21, 22, or 23, designed  
for inbound or outbound calling to or from handsets, such  
15 as 24 or 25. The base stations 21, 22, or 23 are coupled  
to a node 26 for coupling base stations into a cluster for  
covering a localized area such as an office building or a  
shopping mall. The nodes 26, 26' may be coupled to a  
central network control 28 for operation of a radio  
20 communication system. The nodes 26, 26' are coupled to  
the public switched telephone network 30 through which  
calls are routed to or from a conventional telephone 32  
via connections 30a or 30b established through the public  
switched telephone network 30. When a caller calling from  
25 a handset 24 or 25, wants to place a call, a radio  
communications link is formed with a base station 21, 22,  
or 23 and the call is connected to the conventional  
telephone 32 via the node 26 and the connection 30a. When  
a caller, calling from a conventional telephone 32, wishes  
30 to reach a particular handset subscriber, the caller  
places a call through a connection 30a established through  
the public switched telephone network 30 to a node 26.  
The node 26 instructs the base stations 21, 22, and 23 to  
page for the handset. The handset responds to the page by



signalling the base station 21 in order to couple the handset 24 to the telephone 32.

Channel allocation, whether the call is outbound from the cordless telephone handset or inbound thereto, is handled by each base station 21, 22, or 23. A handset 24 attempts to establish communication with the base station 21, 22, or 23 having the strongest signal at the handset 24. Once communication is initiated between the handset and a base station, the base station 21, 22, or 23 allocates at least one communication channel to the handset 23, 24, or 25. The channel is allocated in accordance with the preferred embodiment of the present invention by selecting a channel from a Preferred Channel List (PCL) as described below. The PCL is maintained at each base station 21, 22, or 23, independently, allowing fully distributed channel allocation throughout the system, therefore not overburdening a node 26 or the central control 28.

Referring to FIG. 2, each base station 21a-c, 22a-b, and 23a-b, has an associated coverage area 40a-c, 41a-b, and 42a-b, respectively. For example, base station 21b will provide communications for any handset within coverage area 40b. The coverage area provided by a base station may vary based upon materials forming the environment in the coverage area. In cordless telephone systems, the base stations are preferably positioned to form coverage areas such that a cluster of base stations cover a designated area such as a shopping mall, an airport, an office complex, or a designated geographic area. When allocating channels for use and assigning channels to the handsets as requested, the base station 21b considers the history of channel quality for channels used in the area 40b, as described below.

Referring to FIG. 3, a block diagram of a base station 21 in accordance with the present invention is

shown. Communication with the base station is provided by an antenna 54 and a conventional communications transceiver 56. The communications transceiver is coupled to a call handler block 58 of a controller 60. The call handler block 58, in accordance with the present invention, receives the call initiation requests, transmits the allocation of communication channels to handsets, and maintains the channel for communication with the handset until the service or call is disconnected.

The controller 60 controls the operation of the base station 21 for all operations. The controller 60, in accordance with the present invention, also comprises a channel allocator block 62 for allocating channels. The controller 60 and the channel allocator 62 of the preferred embodiment of the present invention are coupled to a memory 64 for accessing and maintaining information on the system's channels. In accordance with the preferred embodiment of the present invention, a Preferred Channel List (PCL) is stored therein. The PCL is a list developed from all of the channels available to the system. Each base station typically uses only a subset of the channels available to the system. The controller 60 maintains the PCL by measuring and recording a history of channel quality measurements as explained below.

In accordance with an alternative embodiment of the present invention, an assigned channel list and a borrowed channel candidate list are stored in the memory 64. The controller 60 is coupled to the node 26 and may allow communication with the node 26 or the network center 28 (FIG. 1) via a network connection 68 for maintenance of the assigned channel list and the borrowed channel candidate list stored in the memory 64.

Referring to FIGs. 4 and 5, the channel allocation method of the preferred embodiment of the present invention is described. The fully distributed dynamic

channel allocation method of the present invention combines the advantages of the fixed and dynamic channel allocation methods. For example, the method of the present invention has channel allocation initialization and is adaptive to a slowly changing environment like the dynamic channel allocation methods. In addition, in heavy traffic the distributed dynamic channel allocation method of the present invention simulates an optimal fixed channel allocation method in the sense that the method provides an improved compact layout of channel reuse. Since all the decisions are based on local measurements at the base station, the channel allocation method of the preferred embodiment of the present invention is simple and fully distributed in the sense that no direct connection between base stations is necessary. This allows for independent operation by each base station and does not burden the nodes 26 or the central network control 28 (FIG. 1) for channel allocation.

The measurements made by the base stations concern the quality of a channel in the system. The quality is described by a function  $f$  describing successful channel service, where a channel service is defined to be successful if it is neither blocked nor interrupted. For example,

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$$f(p_s, \text{Margin}, cq)$$

where  $p_s$  is the probability of success or  $P(\text{success})$ ; Margin is  $\text{Equality} > \text{Threshold}(\text{quality} - \text{Threshold})$ , that is, Margin is the mean value of  $(\text{quality} - \text{Threshold})$  under the condition of  $\text{quality} > \text{Threshold}$ , where quality is any measurement defined by the system; and Threshold is the lower bound of the quality for a channel to be considered as a good channel; and  $cq$  is the current channel quality.

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The requirements for the quality function are that it should be an increasing function of  $p_s$  and  $c_q$  and a decreasing function of Margin. The definition of the  
5 quality function for a channel (f) in accordance with the preferred embodiment of the present invention is:

$$f(p_s, \text{Margin}, cq) = p_s \times \text{Margin}^{-L} \times cq^N$$
$$= \frac{N_s}{N_s + (M \times N_i) + N_b} \times \text{Margin}^{-L} \times cq^N$$

5

where L, M, N : weights defined by the system,  
for example L=4.0, M=10, and  
N=1.0;

N<sub>s</sub>: number of successful calls;

10

N<sub>b</sub>: number of blocked calls; and

N<sub>i</sub>: number of interrupted calls.

The method of channel allocation of the preferred embodiment present invention allocates channels with a combination of a high probability of success and a low probability of being blocked or interrupted. This is accomplished by defining p<sub>s</sub> to include not only the effects of the number of successfully completed calls and number of blocked calls but also the effect of the number of interrupted calls with an assigned weight M. Preferably M is set equal to 10, thereby weighting the occurrence of interrupted calls ten to one over blocked or successful calls. In addition, the method of the preferred embodiment of the present invention advantageously allocates channels with a low margin and a high channel quality. The lower margin preferably allocates channels not too good, that is, channels usually operating at the quality approaching the threshold from above.

30 In accordance with the preferred embodiment of the present invention, each base station in the system maintains a Preferred Channel List (PCL). The channels are listed in a decreasing sequence of the values of their quality function. The channel quality of the channels for  
35 a base station will be updated whenever any of the

following three recordable events happens: (a) a service (e.g., a call) is finished successfully; (b) a service is interrupted; or (c) a channel is rejected for service initiation due to bad quality (i.e. blocked). The PCL is maintained in memory 64 (FIG. 3) of each base station 21. The controller 60 (FIG. 3) of the base station updates the Preferred Channel List (PCL) while the channel allocator 62 (FIG. 3) utilizes the PCL for allocating channels in response to service initiation requests.

Referring to FIG. 4, the PCL updating process of the base station controller 60 in accordance with the preferred embodiment of the present invention is shown. When a base station is first installed in the system 100 it assigns an initial probability  $p_{s0}$  greater than zero to  $p_s$  (i.e.,  $p_s = p_{s0} > 0$ ) 102 and the Margins are initialized 103. The initial probability of success ( $p_{s0}$ ) is a parameter that affects the grade of service of a base station when the base station is in its initialization stage. If the  $p_{s0}$  is assigned a small value the un-used channel will not be used unless the grade of service of the used channel degrades a great amount (i.e., dropping lower than  $p_{s0}$ ). The assignment of the initial value of  $p_s = p_{s0} > 0$  makes the value of the quality function of the used channel and that of the un-used channels comparable. From the definition of the quality function we see that the quality function is only meaningful for used channels having a quality function  $f(p_s, \text{Margin}, cq) > 0$ . By assigning  $p_s = p_{s0} > 0$ , for example 0.5, an un-used assigned channel will be considered for allocation before a used channel only if the un-used channel has a higher quality value than that of the used channel. In case the initial value of the channel is assigned  $p_s = p_{s0} = 0$  the un-used channels would never be considered because the quality value of the used channel would always be higher than that of the un-used channels. The Margins are also initialized

103 to equal values. The initial PCL is then formed by randomly positioning the channels of the system and stored 104.

Processing then awaits the occurrence of one of the  
5 three recordable events on a channel: (a) a call on the channel is finished successfully 106; (b) an initiation request on the channel is blocked 118; or (c) a call on the channel is interrupted 122. The channel allocator 62 signals the controller 60 that a block event has occurred  
10 118 when a call initiation request is blocked. The call handler 58 follows the progress of a call on a channel and signals the controller 60 that a succeed event has occurred 106 upon successful completion of the call. And the call handler 58 signals the controller 60 that an  
15 interrupt event has occurred 122 when the call handler 58 is signalled by the handset that the call is interrupted.

If a succeed event on a channel has occurred (i.e., a call on the channel is finished successfully) 106, the success event counter,  $N_s$ , for that channel is incremented  
20 by one 108 and the Margin for that channel is updated 110. Previous proposals for using a channel with a measured Margin use an instantaneous value for the Margin which is only updated when needed, i.e., at the call setup stage. The method of the present invention, though, updates the  
25 Margin 110 after each successful completion of a call 106, thereby utilizing a more meaningful Margin based on the history of the channel. The Margin being updated after each successful call realizes a mean Margin value which advantageously improves the concept of Margin over the  
30 prior instantaneous margin measurement. Also, the margin value after a successful call is a truer measurement of channel Margin than the margin measured at call connection setup.

After updating the Margin 110, the probability of  
35 success,  $p_s$ , for the channel is then updated 112 and the

quality function,  $f$ , for the channel is updated 114. The Preferred Channel List (PCL) is adjusted 116 in accordance with the updated quality function,  $f$ , value. For example, the success event could increase the quality function,  $f$ , for the channel and may allow the channel to move to a higher position in the PCL.

After adjusting the PCL 116, processing returns to await occurrence of one of the three recordable events 106, 118, or 122. If a block event on a channel has occurred 118, the block event counter  $N_b$  for that channel is incremented by one 120. The probability of success  $p_s$  for the channel is then updated 112, the quality function  $f$  for the channel is updated 114, and the PCL is adjusted 116 in accordance with the updated quality function value. Likewise, if an interrupt event on a channel has occurred 122, the interrupt event counter  $N_i$  for that channel is incremented by one 124, the probability of success ( $p_s$ ) for the channel is updated 112, the quality function ( $f$ ) for the channel is updated 114, and the PCL is adjusted 116. After each adjustment of the PCL 116, processing returns to await occurrence of one of the three recordable events 106, 118, or 122.

In this manner, a current Preferred Channel List (PCL) is maintained wherein the channel with the highest value of the quality function measured on past history is at the top of the PCL. The other channels are positioned in the PCL at ever decreasing values of the quality function measured. As stated above, the channel allocation method of the preferred embodiment of the present invention is fully distributed in that each base station stores a PCL in its memory 64 (FIG. 3) and the controller 60 maintains, or updates, the PCL as events occur.

Referring to FIG. 5, the operation of the channel allocator 62 of the base station 21 of FIG. 3 in



accordance with the preferred embodiment of the present invention is shown. The method for channel allocation of the present invention attempts to assign the channel with the best quality (i.e., the channel with the highest value of the quality function) whenever possible. The allocated channel would be the first channel in the Preferred Channel List (PCL) that is in a free timeslot (in the case of one transceiver per base station) and currently in good quality. Alternatively, channel allocator 62 could allocate a number of channels in good quality as a list of channels is decreasing preference to the base station (an allocated channel list, ACL), from which the handset would choose the first acceptable channel and identify to the base station the acceptable channel.

After the base station is put into service 125, the channel allocator 62 awaits a request for a channel assignment 126. When a channel assignment request has been received 126, the PCL is examined to determine if the next free (e.g., first) channel on the PCL is available 128. If there are no free channels available for allocation 128, the channel allocator 62 signals the controller 60 to inform the handset that no channel is available for allocation 130 and processing awaits the next channel assignment request.

If a free channel on the PCL is available for allocation 128, it is determined whether the timeslot for the channel is busy 132 (assuming there is one transceiver 56 per base station (FIG. 3)). If the channel's timeslot is busy 132, the PCL is examined to determine if another free channel on the PCL is available for allocation 128. If the channel's timeslot is not busy 132, the current channel quality  $cq$  is measured 134 and it is determined from the channel quality measurement whether the channel is now a good channel 136. Though the channel may occupy a high position in the PCL because it had previously been

measured as a good channel, the channel may not now be a good channel. If the channel is not now a good channel 136, the channel allocator 62 signals the controller 60 that a block event for the channel has occurred 138 and the next free channel on the PCL is examined to determine if it is available 128. If, on the other hand, the channel is measured as a good channel 136, the channel is assigned for communication 140. As mentioned above, the channel allocator could perform a number of iterations of measuring channels to derive a predetermined number of good channels (such as four) and inform the handset of the good channels in decreasing preference (the ACL) 140. Processing awaits a reply from the handset for a predetermined time, M seconds 141. If a positive reply from the handset is received identifying an acceptable channel within M seconds, the channel accepted by the handset is utilized for communication and the channel allocator 62 signals the controller 60 that a channel assignment (i.e., a channel initiation request) has succeeded 142. Processing returns to await the next channel assignment request 126. If a positive reply is not received within M seconds 141, processing returns to step 126.

In this manner, the PCL is utilized to allocate channels for communication. The method of channel allocation of the present invention utilizes the mean Margin as a parameter of the quality for a channel. This parameter makes possible optimizing channel reuse in a distributed fashion. More particularly, taking the mean Margin as a parameter of the quality function, a channel with a lower mean Margin has a higher priority over channels with higher mean Margins, leading to better channel reuse. The improved channel reuse is a result of the relationship that the smaller the mean Margin, the more compact the layout of the co-channels will be and,

consequently, the higher the channel reuse. Previous proposals for using a channel with a small Margin use an instantaneous value for Margin which is only measured at the call initiation stage. Due to shadowing and fading effects and its vague meaning, an instantaneous value for Margin is almost meaningless. The method of the present invention, though, uses a mean Margin which is updated after each successful completion of a call, thereby utilizing a more meaningful mean Margin based on the history of the channel.

Referring to FIG. 6, the handset 24 of the DECT system 20 (FIG. 1) comprises an antenna 170 coupled to a transmitter circuit 172 and a receiver circuit 174. The microprocessor controller 178 receives a signal from the receiver circuit 174 indicating the received signal strength (the RSSI signal).

A time division duplexer 176 controls the signal provided to the transmitter 172 and received from the receiver 174 to facilitate two-way communications by synchronizing communications to the timeslot allocated for communications. The operation of the timed division duplexer 176 is controlled by a signal from the microprocessor controller 178. The microprocessor controller 178 provides a signal to a frequency synthesizer 180 for controlling the operation thereof. The frequency synthesizer 180 supplies the operating frequency information to the transmitter 172 and the receiver 174 for modulation and demodulation of the communication signal. The controller 178 is also coupled to a memory 179 for accessing and updating stored information.

The signal received by the receiver 174 or transmitted by the transmitter circuit 172 is a digitally encoded signal which passes through a codec 184 for digital-to-analog or analog-to-digital conversion. The

signal received via the receiver circuit 174 and converted by the codec 184 is supplied as an analog signal to audio circuitry 186 and thence to a speaker 188. Likewise, an analog signal received from a microphone 190 passes  
5 through the audio circuitry 186 and is converted to a digital signal by the codec 184 before being provided to the transmitter circuit 172. In addition, control signals, such as call initiation requests and call disconnect requests, can be provided from the controller  
10 178 to the transmitter 172 for transmission therefrom. Control signals received by the receiver 174 are likewise provided to the controller 178.

For other operations, such as dialling up a telephone number, user controls 183 provide appropriate  
15 signals to the microprocessor controller 178. In addition, the microprocessor controller 178 supplies a signal to a display driver 192 for generation of a visual message for presentation to the user on a display 194.

Referring to FIGS. 7, 8, and 9, a flow chart of the  
20 operation of the controller 178 of the handset 24 (FIG. 6) is shown. Referring to FIG. 7, the process of the controller 178 (FIG. 4) starts 200 with the power up of the handset. The controller can perform three functions while interfacing with a base station: initiate a call  
25 202 between the handset and the base station, finish a call 204, and monitor a call 206. If the controller 178 is requested to initiate 202 a call, a call initiation routine 210 is performed, after which processing returns to await the next calling task request 202, 204, 206. If  
30 call finishing 204 is detected, the handset sends a disconnect request 212 to the base station after which processing returns to the idle loop to await one of the calling task requests. Finally, if call monitoring 206 is detected, a call monitoring routine 214 is performed,  
35 after which processing proceeds to await the next calling

task request 202, 204, 206. If none of the calling task requests are received, processing remains in an idle loop 202, 204, 206 awaiting one of the calling task requests.

Referring to FIG. 8, before the call initiation  
5 routine 210 begins, the handset locks to a base station and learns the Preferred Channel List (PCL) of that base station. The handset could lock to the base station by taking a quality measurement of a channel broadcast by the base station, such as measuring the RSSI value  
10 (proportional to the power of the signal broadcast by the base station) or calculating a signal to noise and interference ratio (S/I). The Preferred Channel List (PCL) of the base station is downloaded into the memory 179 (FIG. 6). The handset monitors the environment by  
15 regularly scanning channels to lock to the strongest base station. The base station broadcasts its PCL on its channel regularly or on demand. Thus, the handset is locked to a base station and knows the PCL of the base station before call initiation 210.

20 First, the Preferred Channel List (PCL) of the selected base station is examined to determine if the next (e.g., first) channel in the PCL is available 222. If a channel is available from the PCL 222, the quality of the channel is measured to determine if the channel quality is  
25 above a threshold  $Th$  224. If the channel quality is not above the threshold  $Th$  224, the next channel in the PCL is selected, if available 222. If the channel quality is above the threshold  $Th$  224, a connection request is sent to the base station using the channel 226. If a positive  
30 reply is not received from the base station within a predetermined time period  $Ti$  228, the next channel in the PCL is selected, if available 222. If a positive reply is received from the base station within  $Ti$  seconds 228, the channel quality of the allocated channel is measured to  
35 determine if it is a good channel 229. If the allocated

channel is a good channel 229, a communication connection (i.e., radio link) is setup between the handset and the base station using the channel 230 and processing returns 232 to await the next calling task request 202, 204, 206.

5        If the allocated channel is not good 229, processing awaits reception of a positive reply from the base station for  $T_i+d$  seconds 234 indicating an additional allocated channel. If a positive reply is received within  $T_i+d$  seconds 234, the channel quality of the additional  
10 allocated channel is measured to determine if it is a good channel 229. If a positive reply is not received within  $T_i+d$  seconds 234, the user is informed that the channel connection request failed 236 (i.e., no channel is available for allocation from the selected base station)  
15 and processing returns 232 to await the next calling task request 202, 204, 206. Also, when there are no channels available for allocation 222, the user is informed that the channel connection request failed 236 and processing returns 232 to await the next calling task request 202,  
20 204, 206.

Referring next to FIG. 9, the call monitoring routine 214 is shown. While a call is in progress 214, the channel quality is monitored by the controller 178 (FIG. 6) to determine whether the channel quality has  
25 become poor for continued use 250. The channel quality is poor when the quality falls below a threshold  $Th$  250. When it is determined that the channel quality has fallen below the threshold 250, the call initiation routine 210, as described above, is accessed. If a call is not  
30 successfully initiated within a predetermined time 252, the user is notified that the call is suspended 254 and a call interrupt notice is sent to the the base station 256 for maintaining the Preferred Channel List, as described above. Processing returns 257 to the idle loop 202, 204,  
35 206 (FIG. 7) to await one of the calling task requests.

If a call is successfully initiated on another channel 252, a "handover" is performed, handing the call over from one channel to another. A new connection is established between a base station and the handset on the new channel 258. A disconnect request is sent on the old channel 259 to remove the old connection. Processing then returns 257 to the idle loop 202, 204, 206 (FIG. 7) to await one of the calling task requests.

The preferred embodiment of the present invention is an apparatus and method for fully distributed dynamic channel allocation. An alternate method for channel allocation utilizing the present invention is an optimal dynamic channel allocation. The alternate method of channel allocation described herein combines fixed channel allocation and dynamic channel allocation and optimizes channel reuse by keeping the reuse distances (i.e., the distances between co-channel base stations) as small as possible with respect to the changing environment. The channel allocation method allows channel borrowing functions under light traffic. In heavy traffic, the alternate method described hereinbelow approaches an optimal fixed channel allocation method with a compact layout of channel reuse in respect to a slowly changing environment. In the channel allocation adjustment process described herein, a meaningful measurement of the channel quality is the S/I measured when all the first tier co-channels are busy. The concept of locally heavy loaded periods is introduced to allow meaningful measurement of the channel quality. The locally heavy loaded period of channel *i* is detected either by local measurement of the environment (a distributed version) or by receiving messages from a center (a central control version) such as the network center 28 (FIG. 1).

At any one time, a subset of the channels available to the system are used by a base station. These

channels are "assigned" to the base station and the base station is the "home site" of these channels. The criteria for improved channel allocation in accordance with the method of the present invention is that channel i  
5 will be "assigned" to site j if channel i offers guaranteed quality of service to site j unless some other site borrows it, and site j has the most efficient usage of channel i at the particular time period.

In the alternate embodiment, the quality of a  
10 channel is measured by the signal to noise plus interference ratio (S/I). The minimum required quality for the channel to be used is defined by the threshold--Th. A channel is found to be in poor quality if  $S/I < Th$ . A channel is perfect if  $0 \leq S/I - Th \leq \epsilon$  where  $\epsilon$  is a  
15 given constant which defines the sensitivity of the channel allocation method. A channel is found in too good quality if  $S/I \gg Th$ .

Making channel allocation decisions based on the measurement of S/I in accordance with the present  
20 invention results in advantages over systems that make decisions based on a deductive method. For example, the method of the present invention is simple, accurate, and effective. Though S/I measurement is simple, the S/I may have a vague meaning: e.g., if S/I is too good the reason  
25 may be either all of the co-channels are not busy or all of the co-channels are too far away; or if the S/I is poor the reason may be some other site is borrowing the channel or some co-channel sites are too close. The vague meaning of S/I indicates that a channel allocation method based  
30 solely on a single measurement of S/I will lead to poor performance. The channel allocation method of the present invention, therefore, is concerned with a worst case S/I measurement. The worst case S/I of channel i,  $SI_w(i)$ , occurs when all the main co-channels (first tier) of  
35 channel i are in use.  $SI_w(i)$  can be derived from m



independent measurements ( $m \geq 1$ ), where the probability,  $P_{S/I}$ , that the worst case S/I cannot be found in  $m$  independent measurements is a function of the mean idle-to-busy ratio:

$$P_{S/I} \leq \left(1 - \frac{1}{(1+r)^n}\right)^m$$

where  $n$  is the number of co-channels; and  
 $r = \max_k (E_k(I_1)/E_k(B_1))$ , where  
 $k$  designates the co-channel base stations.

10 The present invention advantageously utilizes the measurement S/I with the concept of locally light or locally heavy loaded periods to optimally allocate channels. A channel  $i$  at site  $j$  can be said to be in a locally heavy loaded period if all the important  
 15 interference, the prime co-channels (which are defined for simplicity as the first tier co-channels) are busy. When not locally heavy loaded, a channel is considered locally lightly loaded.

If a measurement S/I is too good in locally heavy  
 20 loaded period we are still not quite sure if the quality of the channel is really too good. The problem is solved by taking  $m$  independent measurements during the locally heavy loaded period. The quality of the channel is described by the worst signal-to-noise ratio of channel  $i$ ,  
 25  $SI_w(i)$ , among the  $m$  measurements, which greatly increases the creditability of the measurement.

$$SI_w(i) = \min_{l \in L} (S_l(i)/I_l(i))$$

30 where  $L$  is a set containing the last  $m$  measurements measured after the channel is found to be in a locally heavy loaded period.

Channel borrowing is allowed in locally light loaded periods, but is not allowed in locally heavy loaded  
 35 periods. By allowing channel borrowing only in locally

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light loaded periods and the channel allocation adjustment process only in locally heavy loaded period, the vagueness of the meaning of S/I is removed. For example: if S/I is found in poor quality in a locally light loaded period, the measurement means that an adjacent base station is borrowing the channel (co-channel interference in a light loaded period is not a concern). If S/I is found poor in a locally heavy loaded period, the measurement means that some co-channel site is too close since channel borrowing in accordance with the present invention is not permitted in locally heavy loaded periods.

Each base station in accordance with the alternate embodiment of the present invention performs a channel assignment adjustment whereby a channel is removed from a base station's list of assigned channels. Whenever, in the channel assignment adjustment process, a channel in a locally heavy loaded period is found to be poor, a replacement "home site" for the channel may be found. The new "home site" should have a better quality ( $S/I \geq Th$ ) or a more efficient use of the channel. A channel is poor if  $SI_w(i)$  is less than the threshold,  $Th$ , for channel quality. The channel is too good when  $SI_w - Th > \epsilon$ .

In accordance with the method for optimal dynamic channel allocation, channels are re-assigned through competition. The base station which has better usage of the channel will eventually have that channel assigned thereto. The key point of the strategy is the introduction of a waiting time  $T_i$  for monitoring channel  $i$  where

30

$$T_i = T_s + t_i$$

where  $T_s$  is a constant defined to be long enough so that the base station can discover if the channel  $i$  is in a locally heavy period and the quality of channel  $i$  can be

35

properly measured, and  $t_i$  is a measurement of the margin and importance of channel  $i$  to the associated base station  $j$  defined as

$$5 \quad t_i \propto \begin{cases} \frac{SI_w(i) - Th}{\text{traffic}(j)} & \text{if } SI_w(i) \geq Th \\ \infty & \text{otherwise} \end{cases}$$

where  $\text{traffic}(j)$  is the current traffic at site  $j$ .

The home base stations of channel  $i$  with too good quality of the channel are required to stop using channel  $i$  for at least  $T_i$  seconds so that the other base stations may have the opportunity to make a measurement of the channel. The base station who has the best usage of the channel (i.e. has the smallest  $t_i$ ) will seize the channel and become the new home base station.

15 In accordance with the alternate embodiment of the present invention, the handset 24 maintains a table in the memory 179 (FIG. 6) of base stations within the system to allow the controller 178 to find available channels as described below. The base station table contains a list  
20 of preferred sites organized in descending order of  $P(j) \geq P_t$ , as measured by the controller 178 from the RSSI values of the base station's channels, where  $P(j)$  is the measured signal strength from base station  $j$  and  $P_t$  is the acceptable threshold of signal strength. There may be  
25 only one entry in the table, or even no entries.

Referring to FIG. 10, a flow chart of the operation of the controller 178 of the handset 24 (FIG. 6) when setting up communication with a base station call handler 58 (FIG. 3) in accordance with the present invention is  
30 shown. The call handler 58 interfaces the controller 60 (FIG. 3) of the base station 21 with the handset 24. The operation of the controller 178 of the handset 24 (FIG. 6) in accordance with the alternate embodiment of the present invention operates as described above in reference to

FIGs. 7 and 9. A "handover" during the call monitoring routine (FIG. 9) could alternatively be initiated if the channel quality, as measured by S/I becomes poor (i.e.,  $S/I < Th$ ). The call initiation routine 210', though, differs, as depicted in FIG. 10. The call initiation routine 210' begins by initializing an index  $n(j)$  for every base station in the base station table stored in the memory 179 (FIG. 6) to one 260. When the index  $n(j)$  of a base station  $j$  equals one, processing is examining the base station  $j$  for the first time; when the index  $n(j)$  equals two, the channel of the base station  $j$  have previously been examined.

After initialization of the indexes  $n(j)$  260, the controller 178 examines the table in the memory 179. If there is a base station  $j$  with a channel having a signal power  $P(j)$  greater than or equal to the threshold signal power  $P_t$  and the index  $n(j)$  equals one 262, a connection request is sent to the first such base station in the base station table 264, the connection request indicating that a variable  $x$  should be set to zero. When the variable  $x$  is set to zero, the base station attempts to allocate one of its assigned channels to the handset. If the variable  $x$  is set to one, the base station attempts to allocate one of its borrowed channels to the handset if no good enough assigned channel exists.

After the connection request is sent 264, the index  $n(j)$  for the base station  $j$  is set equal to two 266 and processing awaits reception of a reply 268. If the reply to the connection request is received within a predetermined time and is positive 268, the call is initiated 270 on the allocated channel and processing returns 272 to the idle loop 202, 204, 206 (FIG. 7) to await one of the calling task requests. A positive reply means there is at least one channel allocated in the reply that is acceptable for the handset. If the reply to the

connection request is not positive or a reply is not received within the predetermined time 268, processing returns to step 262.

5 If there are no base stations  $j$  having  $P(j)$  greater than or equal to  $P_t$  and an index  $n(j)$  equal to one 262, then the table stored in the memory 179 (FIG. 6) is examined to determine if there are any base stations  $j$  having  $P(j)$  greater than or equal to  $P_t$  and an index  $n(j)$  equal to two 274. A connection request is then sent to  
10 the first such base station in the base station table 276, the connection request indicating that the variable  $x$  should be set to one. The index  $n(j)$  for the base station  $j$  is then set equal to three 278 and processing awaits reception of a reply 280. If the reply to the connection  
15 request is positive and received within a predetermined time 280, the call is initiated 270 on the allocated channel and processing returns 272 to the idle loop 202, 204, 206 (FIG. 7) to await one of the calling task requests. If the reply to the connection request is not  
20 positive or a reply is not received within the predetermined time 280, processing returns to step 274. In other words, after all of the base stations in the table (base stations with  $P$  less than  $P_t$  are not included in the table) stored in the memory 179 have been sent a  
25 connection request once to allocate an assigned channel and no assigned channel is acceptable, the list is gone through again to send a connection request to the listed base stations to assign a borrowed channel.

30 If there are no base stations  $j$  having  $P(j)$  greater than or equal to  $P_t$  and an index  $n(j)$  equal to two 274, the handset user is informed that the call initiation has failed 282, and processing returns 272 to the idle loop 202, 204, 206 (FIG. 7) to await one of the calling task requests. Call initiation failure occurs when either (a)  
35 there are no base stations with a channel power  $P$  greater

than or equal to the threshold  $P_t$  (i.e., the handset is out of range of any base stations), or (b) a positive reply has not been received from connection requests within the predetermined time to the base stations in the table for allocation of a channel assigned ( $x=0$ ) to the base station or borrowed ( $x=1$ ) by the base station. A call is established if at least one of the base stations in the list stored in the memory 179 has a free channel (if no assigned channels are available, borrowed channels are attempted to be allocated) with  $S/I \geq Th$  as measured at both the base stations, as described below and the handsets. Otherwise the call is blocked.

Referring to FIGs. 11, 12, 13, and 14, the optimal dynamic channel allocation routine is described in accordance with the alternate embodiment of the present invention. The operation of the channel allocator 62 (FIG. 3) starts 300 with the startup of the base station. The channel allocator 62 determines whether a disconnect request has been received 302. If the channel allocator 62 receives a disconnect request 302, a disconnect routine 304 is performed, after which processing moves into an environment monitoring routine 306. If a connection request is received 308, a connect routine 310 is performed. Processing then returns to the environment monitoring routine 306. Otherwise, processing monitors the channel environment via the environment monitoring routine 306. Alternatively, a more efficient method for performing the channel allocation would be to implement the environment monitoring routine with interrupts for activation of the disconnect routine or the connect routine when a disconnect request interrupt or a connection request interrupt are received, respectively.

Referring to FIG. 12, the disconnect routine 304 first determines if the call to be disconnected was on an assigned channel 320. If the call was not on an assigned

channel 320 (i.e., the call was on a borrowed channel), the call is disconnected 321 and processing returns 322 to monitor the environment 306 (FIG. 11).

5 If the call was on an assigned channel 320, it is determined whether a borrowed channel is in use 324. If no borrowed channels are in use, the call is disconnected 321 and processing returns 322 to monitor the environment 306 (FIG. 11). If a borrowed channel is in use 324, the assigned channel is examined to determine if the assigned  
10 channel is acceptable to the borrowed channel traffic 325. If the assigned channel is not acceptable to the borrowed channel traffic 325, the call is disconnected 321 and processing returns 322 to monitor the environment 306 (FIG. 11).

15 If the assigned channel is acceptable 325, the assigned channel is freed (i.e., the call on the assigned channel is disconnected) 326 and a new call is initiated on the assigned channel 327. In accordance with the present invention, a base station advantageously attempts  
20 to return a borrowed channel to its home base station as soon as possible. Thus after a call is finished on an assigned channel, the traffic on a borrowed channel will be transferred to the finished call channel if acceptable and the borrowed channel will be returned to its home base  
25 station. By returning the borrowed channels to their home base stations expeditiously, the present invention advantageously attempts to maintain an ideal environment among the base stations which lend or borrow channels, and the communication traffic utilizes the assigned channels  
30 as far as possible. In accordance therewith, the traffic on one of the borrowed channels in use is transferred 328 to the newly freed assigned channel and the borrowed channel is freed 330. Processing then returns 322 to monitor the environment 306 (FIG. 11).

Referring to FIG. 13, the connect routine 310 begins by examining the channels assigned to the base station to determine if there is at least one free assigned channel in good quality 340. The assigned channels of a base station are always the first choices of traffic. If there is no free assigned channel in good quality 340, the value of x transmitted by the requesting handset is examined to see if x equals one 342. If x does not equal one 342, the handset is requesting an assigned channel of the base station. Thus, if there is no free assigned channels 340 and x does not equal one 342, the requesting handset is signalled that a channel is not available (i.e., a negative reply is sent to the handset requesting connection) 344. Processing then returns 346.

15        If x is equal to one 342, the channels are checked to see if there is a channel to be borrowed 348. A channel can be borrowed if the channel is not "assigned" to the base station but nevertheless has good measured channel quality at the base station and is not in a locally heavy loaded period. If there are no channels to be borrowed 348, the requesting handset is signalled that a channel is not available 344 and processing returns 346. If there is a channel to be borrowed 348, the borrowed channel is allocated for use by the requesting handset 350 and the requesting handset is signalled that a channel is available (i.e., a reply is sent to the handset requesting connection) and the borrowed channel is identified 352. Processing then returns 346 to monitor the environment 306 (FIG. 11).

30        If there is a free assigned channel 340, processing determines whether the base station is lightly loaded 354. If the base station is not lightly loaded 354, a free assigned channel in good quality is allocated 356 for use by the requesting handset and the handset is signalled that a channel is available, the allocated channel being identified

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thereto 358. Processing then returns 346. If the base station is lightly loaded 354, the channel allocator 62 (FIG. 3) attempts to use only a portion of the assigned channels by allocating a free channel in good quality from a designated portion of the assigned channels 360 (for example, the lower indexed channels). In this manner, a lightly loaded base station will try to use a portion of the assigned channels with  $S/I \geq Th$  so that a busy adjacent base station can borrow the un-used channels. Yet an assigned channel should not be used too much. An un-used assigned channel  $i$  will not be used until at least one of the used assigned channels is being used too much. A channel is determined to be used too much if the spacing between successive busy period of the channel,  $T_{spac}$ , is less than  $\tau$ . In other words, in light traffic the channel allocation method of the present invention tries to use a minimum number of channels assigned to it with all the used channels having  $S/I \geq Th$  and  $T_{spac} \geq \tau$ .

The requesting handset is thereafter signalled that a channel (within the designated portion, if possible) is available, the allocated channel being identified thereto 358 and processing returning 346. As described above, the channel allocator 62 (FIG. 3) could alternatively allocate a list of available channels in decreasing preference from which the handset can choose an acceptable channel.

Referring to FIG. 14, the environment monitoring routine 306 sequentially monitors the channels of the radio communication system on each pass through the loop 302, 308, 306 (FIG. 11). In order to sequentially monitor the channels, the environment monitoring routine 306 initially increments a counter  $i$  to examine the next channel  $i$  362. If channel  $i$  is an assigned channel of the base station 364, examination of channel  $i$  at the base station determines whether channel  $i$  is locally heavy loaded 366. As described above, a channel  $i$  is found to

be in a locally heavy loaded period at a base station  $j$  if all the important interferences (i.e. first tier co-channel interferences) are busy.

If channel  $i$  is locally heavy loaded 366, a channel reassignment process takes place. The channel reassignment process adapts to the slowly changing environment and is realized by a channel assignment adjustment operation. The channel assignment adjustment operation will not be started unless the channel  $i$  is found in a locally heavy loaded period at the base station 366. If the channel is found not in a locally heavy loaded period any more 366, the channel assignment adjustment operation will stop and processing will return 368 to the loop 302, 308, 306 (FIG. 11).

The channel assignment adjustment operation first examines the quality of the channel 370. Site  $j$  will release channel  $i$  if the quality of the channel becomes poor ( $SI_w < Th$ ) 370 by removing the channel  $i$  from the base station's assigned channel list 372. Processing then returns 368 to the loop 302, 308, 306 (FIG. 11).

If the quality of the channel is not poor 370, but is determined to be too good (i.e.,  $SI_w - Th > \epsilon$ ) 374, the base station tries to release channel  $i$  so that another base station which has more efficient usage of channel  $i$  may be the new "home site" of channel  $i$ . First, the time since channel  $i$  was last tested is examined 376 to see if it is greater than a predetermined minimum time between channel assignment adjustments,  $T$  seconds. If  $T$  seconds has transpired 376 since the last assignment adjustment of channel  $i$ , use of channel  $i$  is terminated for  $T_i$  seconds 378 to continuously monitor channel  $i$  for channel quality. As described above,  $T_i = T_s + t_i$  where  $T_s$  is a constant and  $t_i$  is a measurement of the quality and importance of channel  $i$  to the base station. If the channel quality  $SI_w$  falls below the threshold  $Th$  during the  $T_i$  seconds of

testing 380, the channel  $i$  is removed from the base station's assigned channel list 372 and processing returns 368 to the loop 302, 308, 306 (FIG. 11).

- 5 If the channel quality is not poor 374,  $T$  seconds has not passed since the last test of channel  $i$  376, or the quality of channel  $i$  does not become poor during the test period 380, processing returns 368 to the loop 302, 308, 306 (FIG. 11) without removing channel  $i$  from the base station's assigned channel list.
- 10 If channel  $i$  is not an assigned channel of the base station 364, the base station can "borrow" channel  $i$  from another base station. If channel  $i$  is in good quality ( $S/I \geq Th$ ) 382, channel  $i$  is not in a locally heavy loaded period 384, and channel  $i$  has been idle for  $K$  seconds 386, then channel  $i$  may be "borrowed" by the base station 388. Processing then returns 368 to the loop 302, 308, 306 (FIG. 11). If channel  $i$  is in good quality ( $S/I \geq Th$ ) 382 but channel  $i$  is in a locally heavy loaded period 384, channel  $i$  can be reassigned to the base station if the
- 20 channel is in good quality for at least  $T_1$  seconds--i.e., channel  $i$  is monitored for  $T_1$  seconds 392 and if the co-channel interference,  $SI_w$ , for channel  $i$  is greater than or equal to  $Th$  during the  $T_1$  seconds 394, the channel  $i$  becomes an assigned channel of the base station 390. If
- 25 the channel quality is not good ( $S/I < Th$ ) 382, or channel  $i$  has not idled for  $K$  seconds 386 when channel  $i$  is not locally heavy loaded 384, or the co-channel interference is measured poor ( $SI_w < Th$ ) 394 when channel  $i$  is heavy loaded 384, processing will return 368 to the loop 302, 308, 306 (FIG. 11) without "borrowing" or reassigning
- 30 channel  $i$ .

The assigned channel list of each base station is maintained in the memory 64 of the base station 21 (FIG. 3). The determination of whether a channel  $i$  is in a

35 locally heavy loaded period at the base station 21a (FIG.

2) requires knowledge of the co-channel locations. Therefore, the co-channel location information on each channel  $i$  is maintained at the node 26 or the central control 28 (FIG. 1). Thus, the optimal dynamic channel allocation method of the alternate embodiment of the present invention is not fully distributed because information necessary to determine the first tier co-channel interference is shared among the base stations.

By now it should be appreciated that there has been provided an apparatus for channel allocation and a preferred fully distributed dynamic channel method and an alternate optimal dynamic channel method of operation of the apparatus which combines the benefits of fixed channel allocation methods and dynamic channel allocation methods and is adaptive to the slowly changing environment while approaching the maximum system capacity with acceptable service quality for any environment.

## CLAIMS

1. In a radio communication system comprising a  
5 plurality of base stations and at least one handset for  
communicating on a plurality of channels, a method for  
channel allocation comprising the steps of:

(a) receiving a request for channel allocation  
at one of the plurality of base stations from one of the  
10 at least one handset; and

(b) allocating one of the plurality of channels  
for the one of the at least one handset to communicate,  
the one of the plurality of channels allocated in  
accordance with a mean margin value of a plurality of  
15 measured margins of channel quality of the one of the  
plurality of channels in relationship to a predetermined  
threshold channel quality.

2. The method of Claim 1 further comprising the  
20 step of (c) recalculating the mean margin value of each of  
the plurality of channels upon each occurrence of a  
successfully completed call thereon.

3. The method of Claim 1 wherein the step (b) of  
25 allocating one of the plurality of channels comprises the  
steps of:

(d) comparing the plurality of channels on the  
basis of the mean margin value of each of the plurality of  
channels; and

30 (e) allocating one of the plurality of channels  
having a lower mean margin value.

4. The method of Claim 1 wherein the step (b) of  
allocating one of the plurality of channels comprises the  
35 steps of:

(f) comparing the plurality of channels on the basis of the mean margin value and a number of prior interrupted calls occurring on each of the plurality of channels; and

5 (g) allocating one of the plurality of channels in accordance with the one of the plurality of channels having a lower number of prior interrupted calls or a lower mean margin value.

10 5. The method of Claim 1 wherein the step (b) of allocating one of the plurality of channels comprises the steps of:

(h) comparing the plurality of channels on the basis of the mean margin value, a number of prior  
15 successfully completed calls, a number of prior interrupted calls, and a number of prior blocked call setup requests occurring on each of the plurality of channels; and

(i) allocating one of the plurality of channels  
20 in accordance with the one of the plurality of channels having a lower mean margin value, a higher number of prior successfully completed calls, a lower number of prior interrupted calls, or a lower number of prior blocked call setup requests.

25

6. The method of Claim 5 wherein the step (h) of allocating one of the plurality of channels comprises the steps of:

(j) allocating one of the plurality of channels in  
30 response to the one of the plurality of channels having a best quality function wherein the quality function is an increasing function of the number of prior successfully completed calls and a current channel quality of the one of the plurality of channels, and wherein the quality  
35 function is a decreasing function of the mean margin

value, the number of prior interrupted calls, and the number of prior blocked call setup requests.

7. In a radio communication system comprising a plurality of base stations and at least one handset for communicating on a plurality of channels, a method for channel allocation comprising the steps of:

(a) one of the plurality of base stations receiving a request for channel allocation from one of the at least one handset; and

(b) allocating one of the plurality of channels for the one of the at least one handset to communicate, the one of the at least one channel allocated in response to determining whether the one of the plurality of channels is assigned to the one of the plurality of base stations and whether the one of the plurality of base stations is lightly loaded.

8. The method of Claim 7 wherein the one of the plurality of base stations has assigned thereto a plurality of assigned channels, the plurality of assigned channels forming a subset of the plurality of channels, and wherein the step (b) of allocating one of the plurality of assigned channels comprises the steps of:

(c) determining whether the one of the plurality of base stations is lightly loaded; and

(d) allocating one of the plurality of assigned channels for the one of the at least one handset to communicate, the one of the plurality of assigned channels allocated from a predetermined portion of the plurality of assigned channels in response to determining that the one of the plurality of base stations is lightly loaded.

9. The method of Claim 8 wherein the one of the plurality of base stations can allocate at least one

borrowed channel, and wherein the step (d) of allocating one of the plurality of channels comprises the steps of:

- (e) determining whether the request for channel allocation requests one of the at least one borrowed channel of the one of the plurality of base stations; and
- (f) allocating one of the at least one borrowed channel in response to determining that the request for channel allocation requests one of the at least one borrowed channel or allocating one of the plurality of assigned channels in response to determining that the request for channel allocation does not request one of the at least one borrowed channel.

10. The method of Claim 8 further comprising the step of (g) borrowing one of the plurality of channels to have it become one of at least one borrowed channel of the one of the plurality of base stations if the quality of the one of the plurality of channels is currently good, the one of the plurality of channels is not locally heavy loaded at the one of the plurality of base stations, the one of the plurality of channels is not one of the plurality of assigned channels, and the one of the plurality of channels has not been in use for a first predetermined period of time.

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11. The method of Claim 8 further comprising the step of (h) reassigning one of the plurality of channels to have it become one of the plurality of assigned channels of the one of the plurality of base stations if the one of the plurality of channels is not one of the plurality of assigned channels, the one of the plurality of channels is locally heavy loaded at the one of the plurality of base stations, and the one of the plurality of channels has a channel quality greater than or equal to



a predetermined channel quality threshold for a second predetermined period of time.

12. The method of Claim 8 further comprising the  
5 step of (i) readjusting an assignment of one of the plurality of assigned channels to have it deleted from the plurality of assigned channels of the one of the plurality of base stations if the one of the plurality of assigned channels is locally heavily loaded at the one of the  
10 plurality of base stations, and the quality of the one of the plurality of assigned channels is not good.

13. A radio communications system for communicating on a plurality of channels comprising:

15 at least one handset; and  
a plurality of base stations, each of the plurality of base stations comprising:

control means for determining an order of said plurality of channels in response to a mean margin value  
20 of a plurality of measured margins of channel quality of each of the plurality of channels in relationship to a predetermined threshold channel quality;

memory means for storing a listing of the plurality of channels in the order determined by the  
25 control means;

input means for receiving a channel allocation request from one of said at least one handset; and

channel allocation means coupled to the input means and the memory means for allocating one of the  
30 plurality of channels in response to the channel allocation request, said one of the plurality of channels determined in response to the listing stored in the memory means.

14. The radio communication system of Claim 13 further comprising event detection means for detecting call interruptions, and wherein the control means determines the order of said plurality of channels in response to the mean margin value of and a number of the call interruptions on each of said plurality of channels.

15. The radio communication system of Claim 13 wherein the detection means further detects successfully completed calls and blocked call setup requests, and wherein the control means determines the order of said plurality of channels in response to the mean margin value of, the number of the call interruptions on, a number of the successfully completed calls on, and a number of the blocked call setup requests on each of said plurality of channels.

16. The radio communication system of Claim 13 further comprising margin measurement means coupled to the event detection means for measuring a margin value of channel quality of each of the plurality of channels in relationship to a predetermined threshold channel quality upon each occurrence of the successfully completed calls, and wherein the control means is also coupled to the margin measurement means for updating the mean margin value upon each measurement of the margin value.

17. The radio communication system of Claim 15 further comprising measurement means for measuring a current channel quality of each of the plurality of channels, and wherein the control means is also coupled to the measurement means for determining the order of said plurality of channels in response to the current channel quality of, the mean margin value of, the number of call interruptions on, a number of successfully completed calls

on, and a number of blocked call setup requests on each of said plurality of channels.

18. A radio communications system for communicating  
5 on a plurality of channels comprising:  
at least one handset; and  
a plurality of base stations, each of the plurality  
of base stations having a plurality of assigned channels  
assigned thereto, the plurality of assigned channels  
10 forming a subset of the plurality of channels, each of the  
plurality of base stations comprising:  
determining means for determining whether one  
of the plurality of channels is one of the plurality of  
assigned channels assigned thereto and for determining  
15 whether the one of the plurality of channels is locally  
heavy loaded or not;  
input means for receiving a channel allocation  
request from one of said at least one handset; and  
channel allocation means coupled to the input  
20 means and the determining means for allocating one of the  
plurality of channels in response to the channel  
allocation request, the one of the plurality of channels  
determined in response to whether said one of the  
plurality of channels is one of the plurality of assigned  
25 channels and whether the one of the plurality of base  
stations is lightly loaded.

19. The radio communications system of Claim 18  
wherein each of the plurality of base stations further  
30 comprises a control means for maintaining a list of the  
plurality of assigned channels, and wherein the channel  
allocation means allocates one of a predetermined portion  
of the plurality of assigned channels in response to the  
determining means determining that the one of the  
35 plurality of base stations is lightly loaded.

20. The radio communications system of Claim 19 wherein the input means comprises:

means for receiving the channel allocation request;

5 and

means for determining whether the channel allocation request requests an assigned channel or a borrowed channel,

and wherein the control means also maintains a list  
10 of at least one borrowed channel, and wherein the channel allocation means allocates one of the at least one borrowed channel in response to the input determining means determining that the channel allocation request requests a borrowed channel or allocating one of the  
15 plurality of assigned channels in response to determining that the channel allocation request does not request one of the at least one borrowed channel.

21. The radio communications system of Claim 20  
20 wherein each of the plurality of base stations further comprises a quality measuring means for measuring whether a channel quality of the plurality of channels is good, and wherein the control means adds one of the plurality of channels to the list of at least one borrowed channel if  
25 the quality measuring means determines the channel quality of the one of the plurality of channels is good, if the determining means determines that the one of the plurality of channels is not locally heavy loaded, and if the control means determines the one of the plurality of  
30 channels is not one of the plurality of assigned channels, and if the control means determines the one of the plurality of channels has not been in use for a first predetermined period of time.

35

22. The radio communications system of Claim 19 wherein each of the plurality of base stations further comprises a quality measuring means for measuring whether a channel quality of the plurality of channels is good, and wherein the control means adds one of the plurality of channels to the list of the plurality of assigned channels if the determining means determines that the one of the plurality of channels is locally heavy loaded, if the control means determines the one of the plurality of channels is not one of the plurality of assigned channels, and if the quality measuring means determines the channel quality of the one of the plurality of channels is greater than or equal to a predetermined channel quality threshold for a second predetermined period of time.

15

23. The radio communications system of Claim 19 wherein the control means removes one of the plurality of assigned channels from the list of the plurality of assigned channels if the determining means determines that  
5 the one of the plurality of channels is locally heavy loaded and if the quality measuring means determines the channel quality of the one of the plurality of channels is not good.

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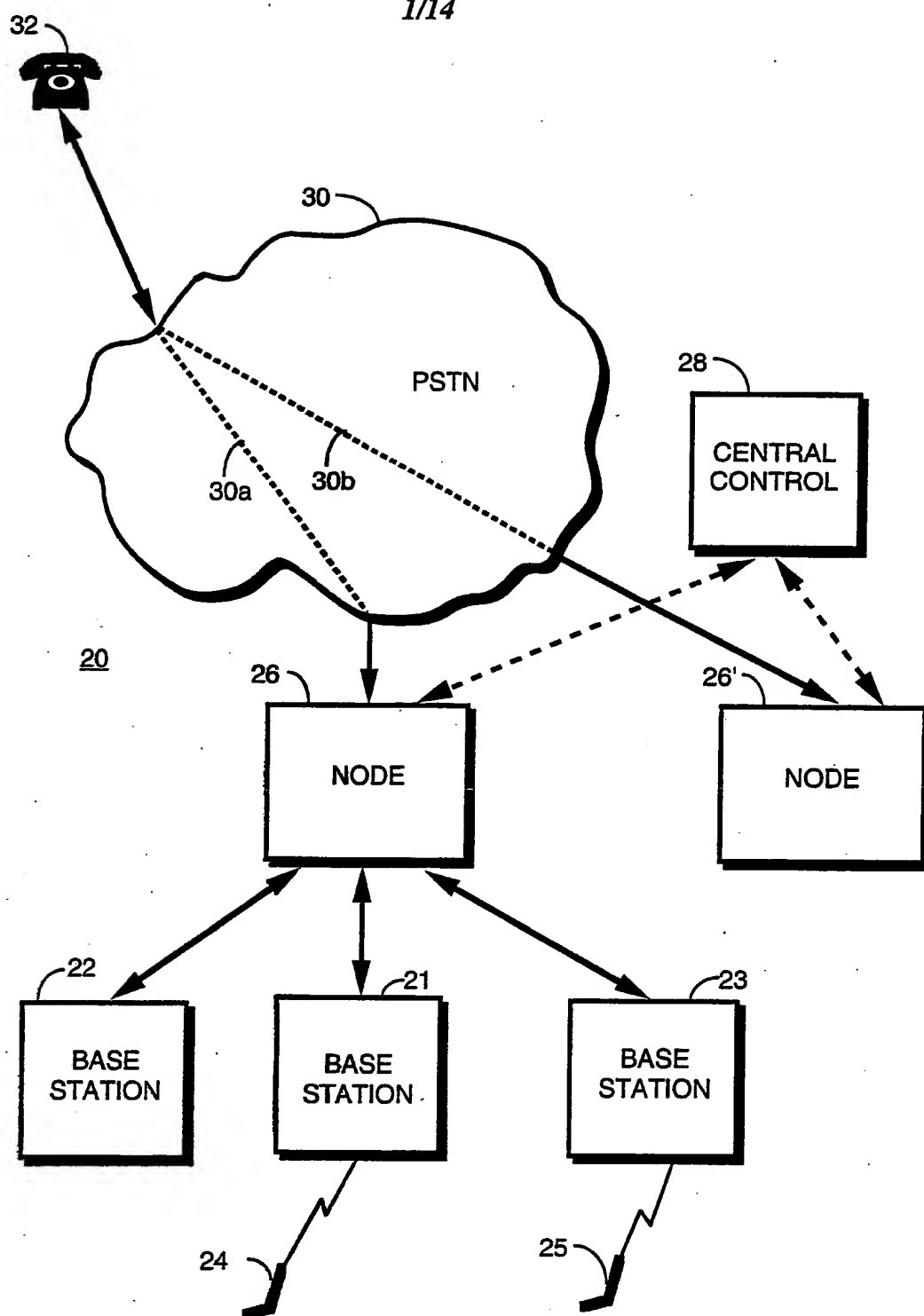
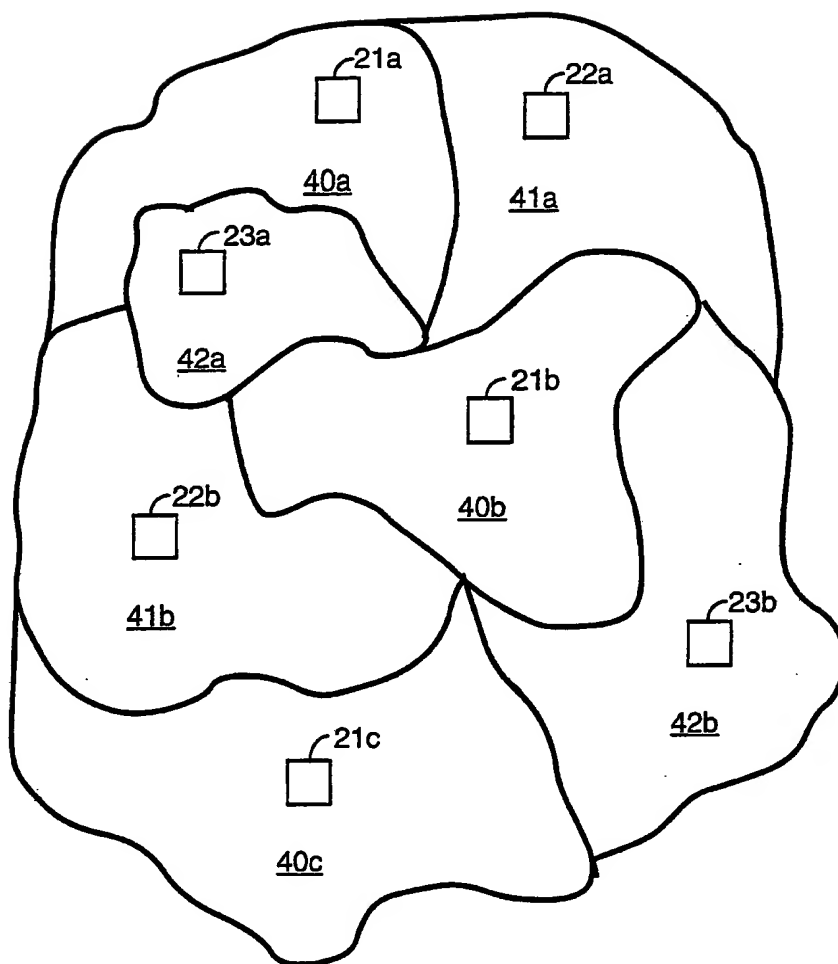


FIG. 1

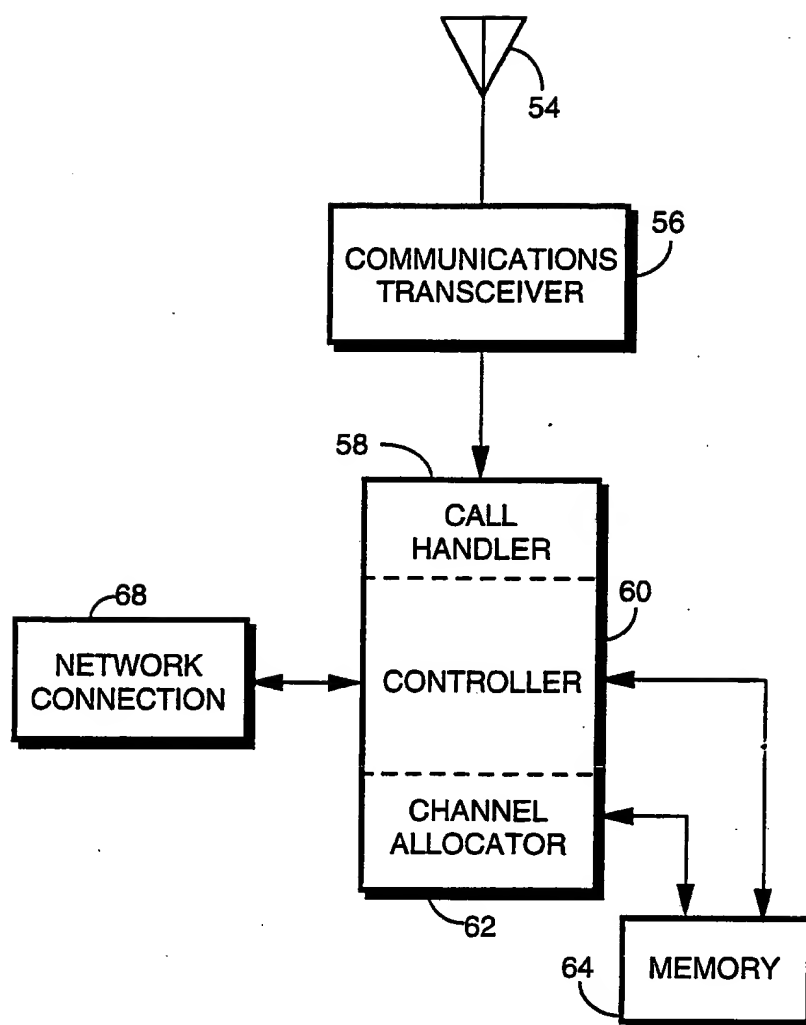
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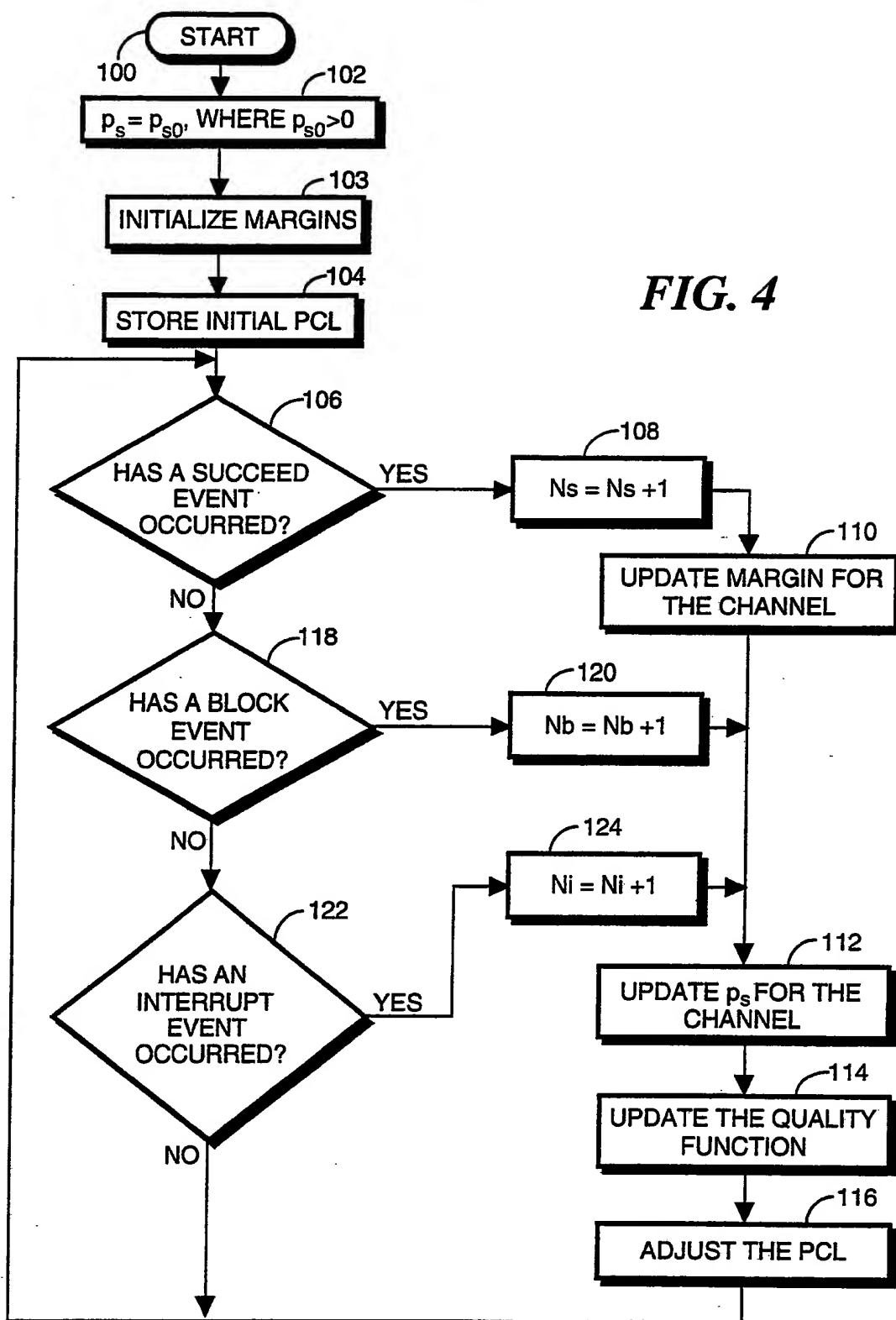
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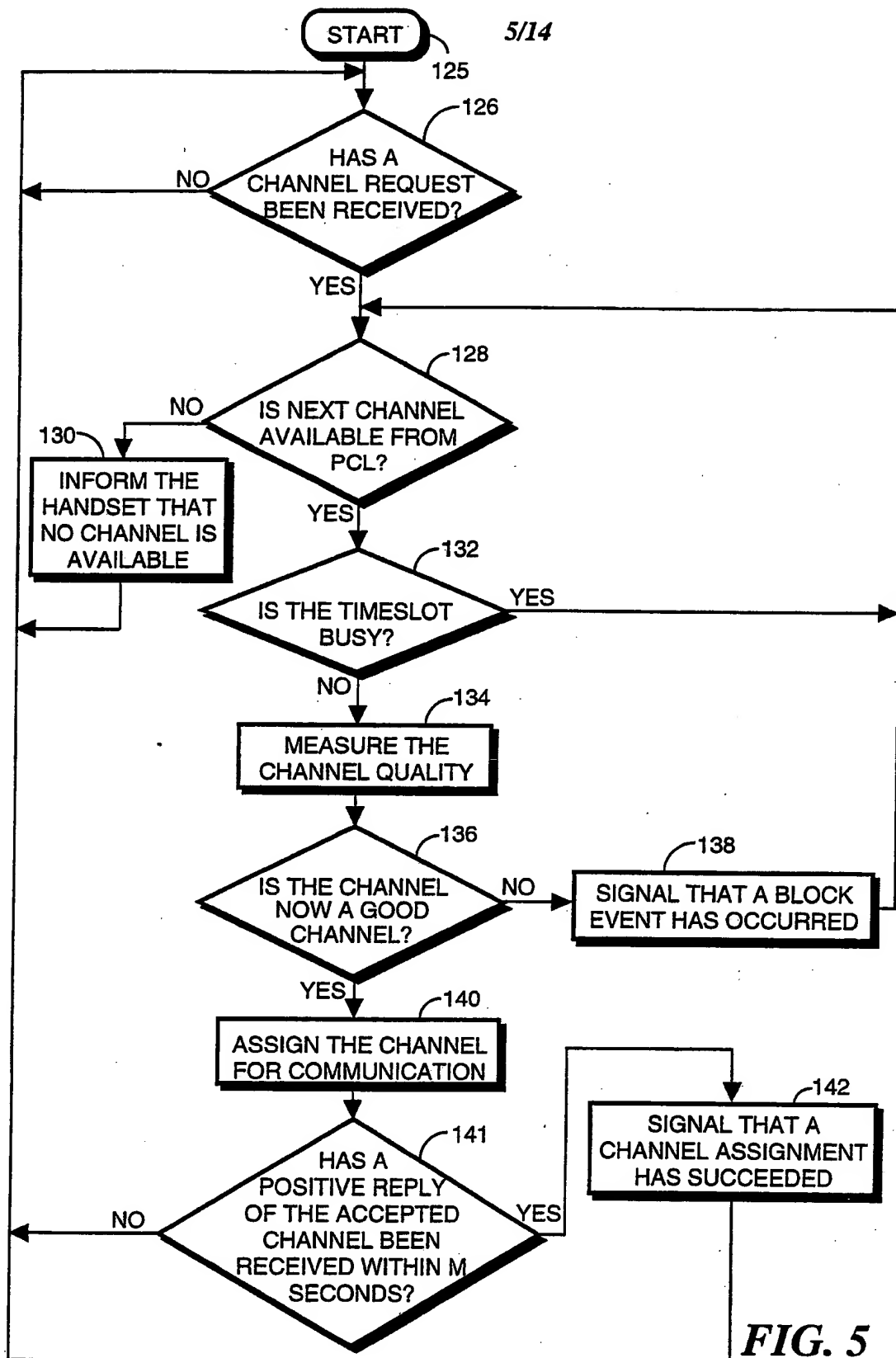


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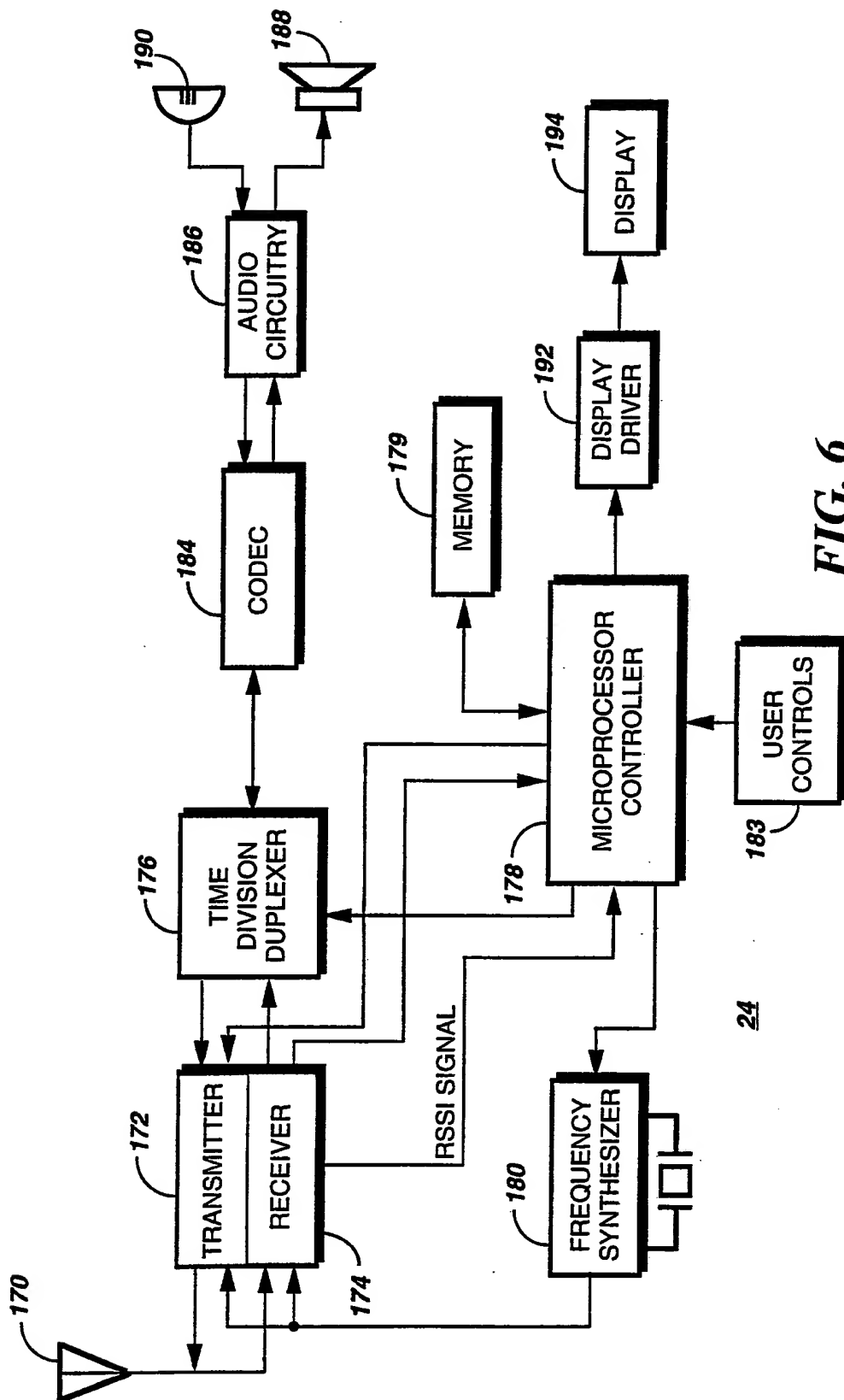
21**FIG. 3**

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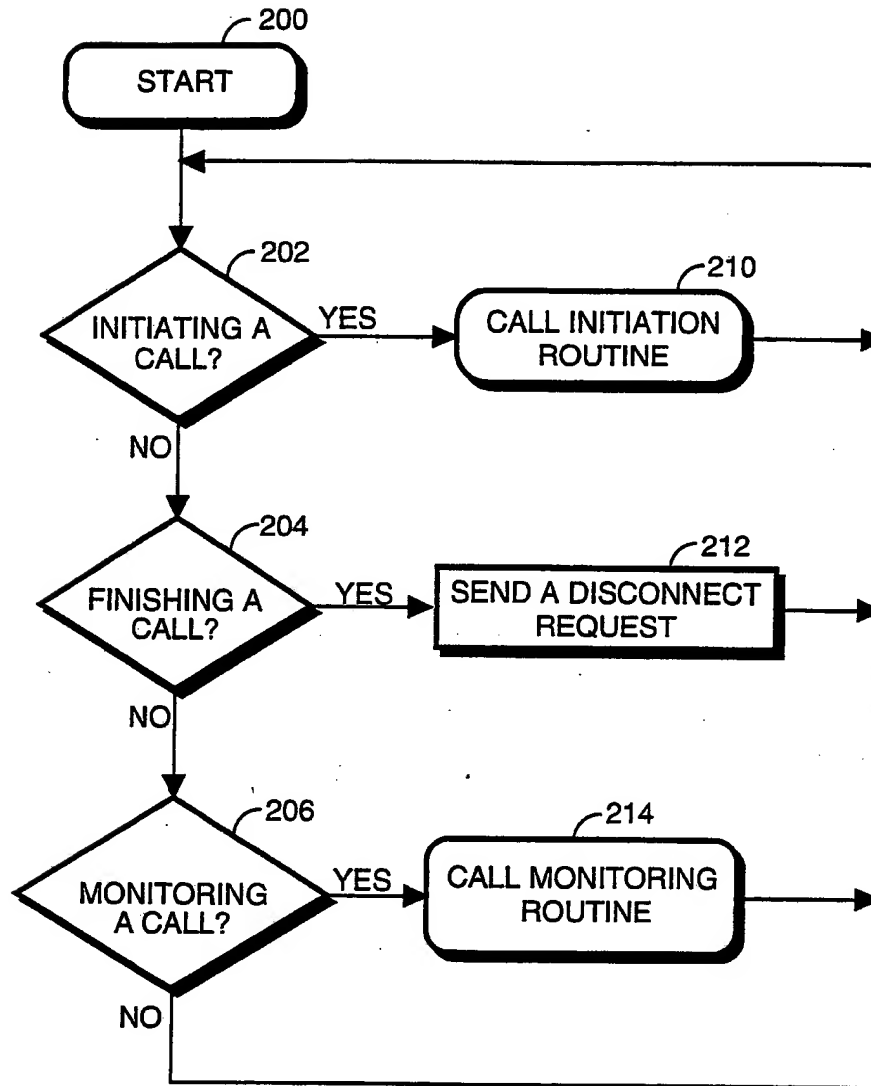
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FIG. 6

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**FIG. 7**

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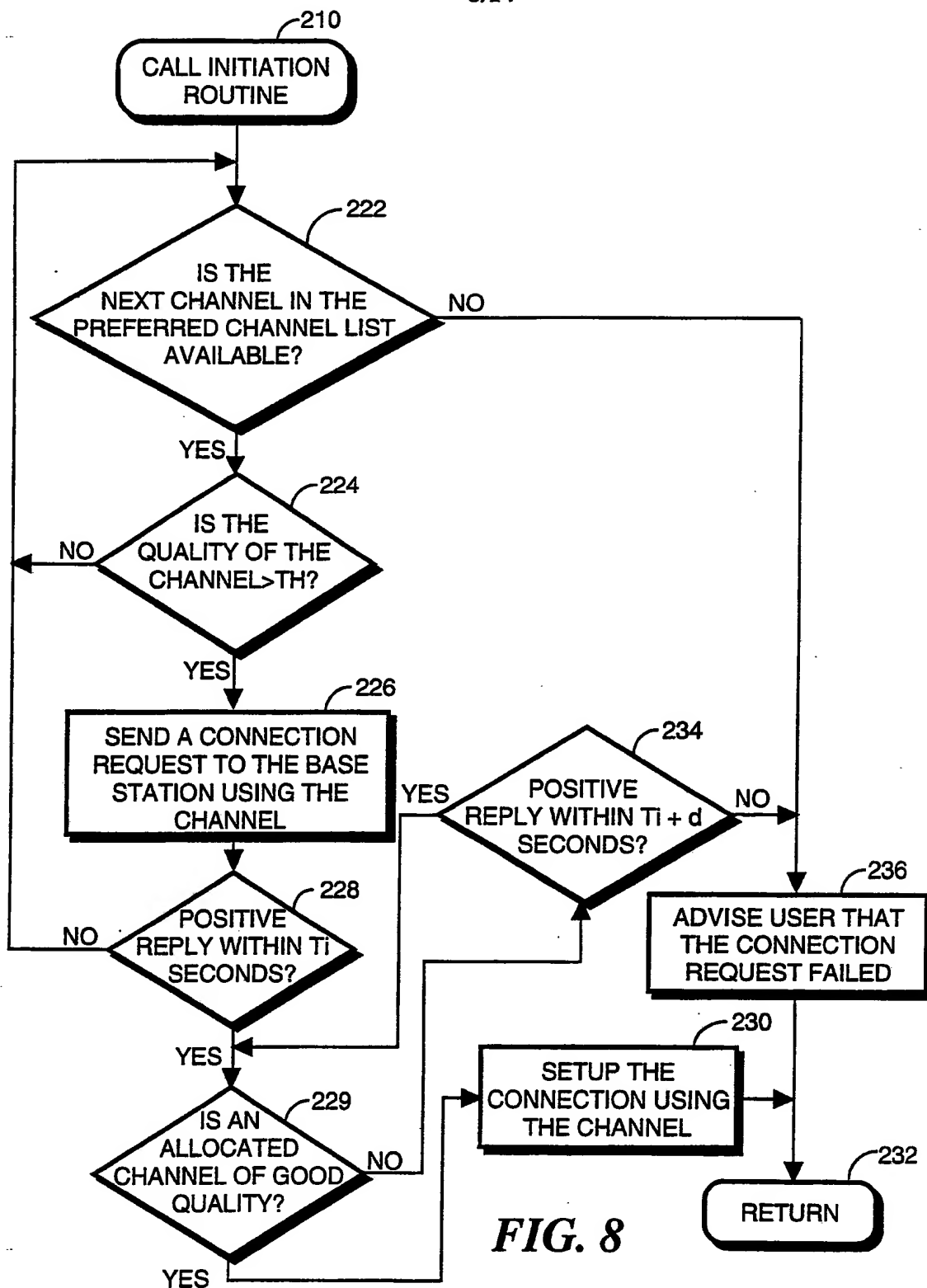


FIG. 8

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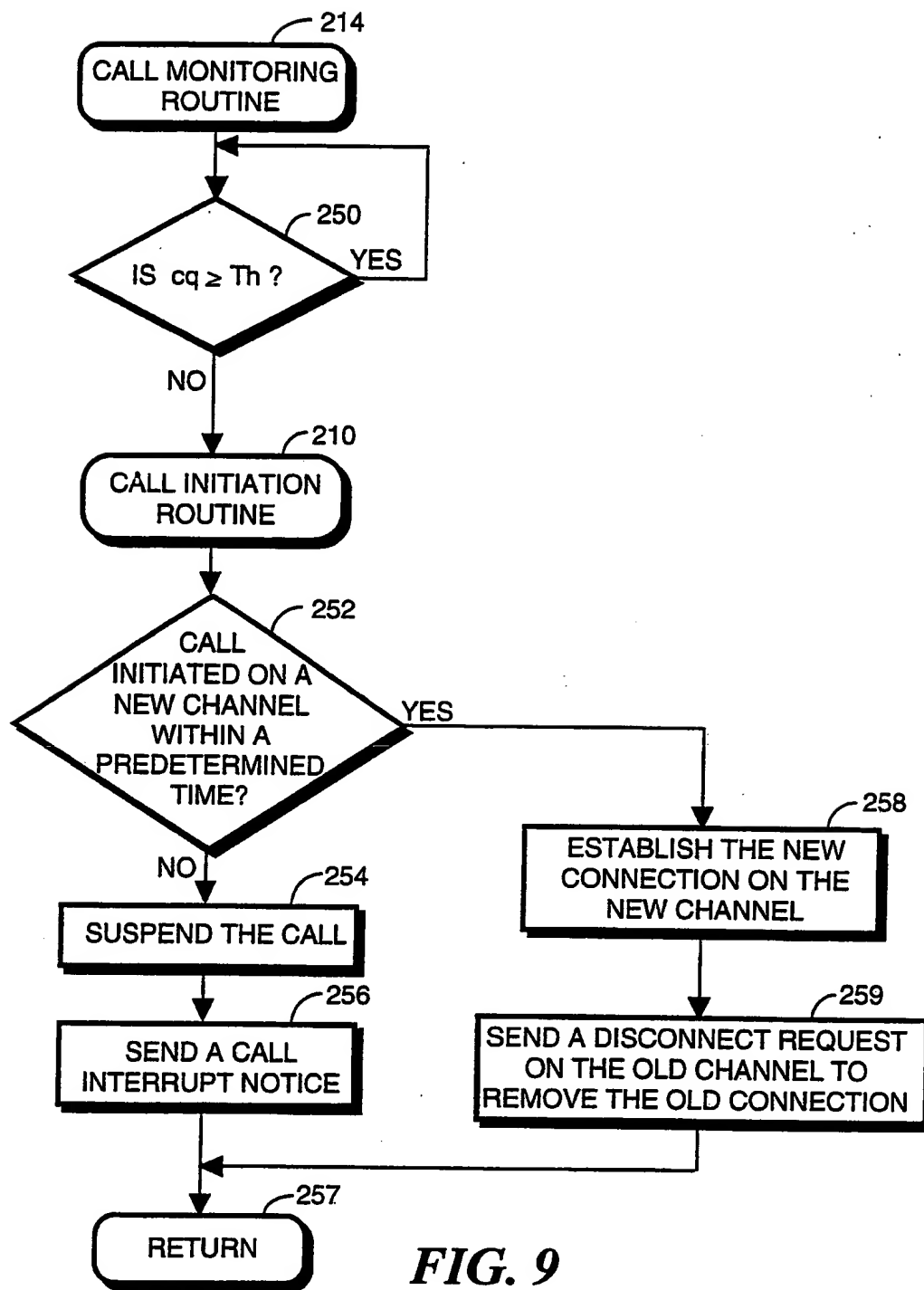
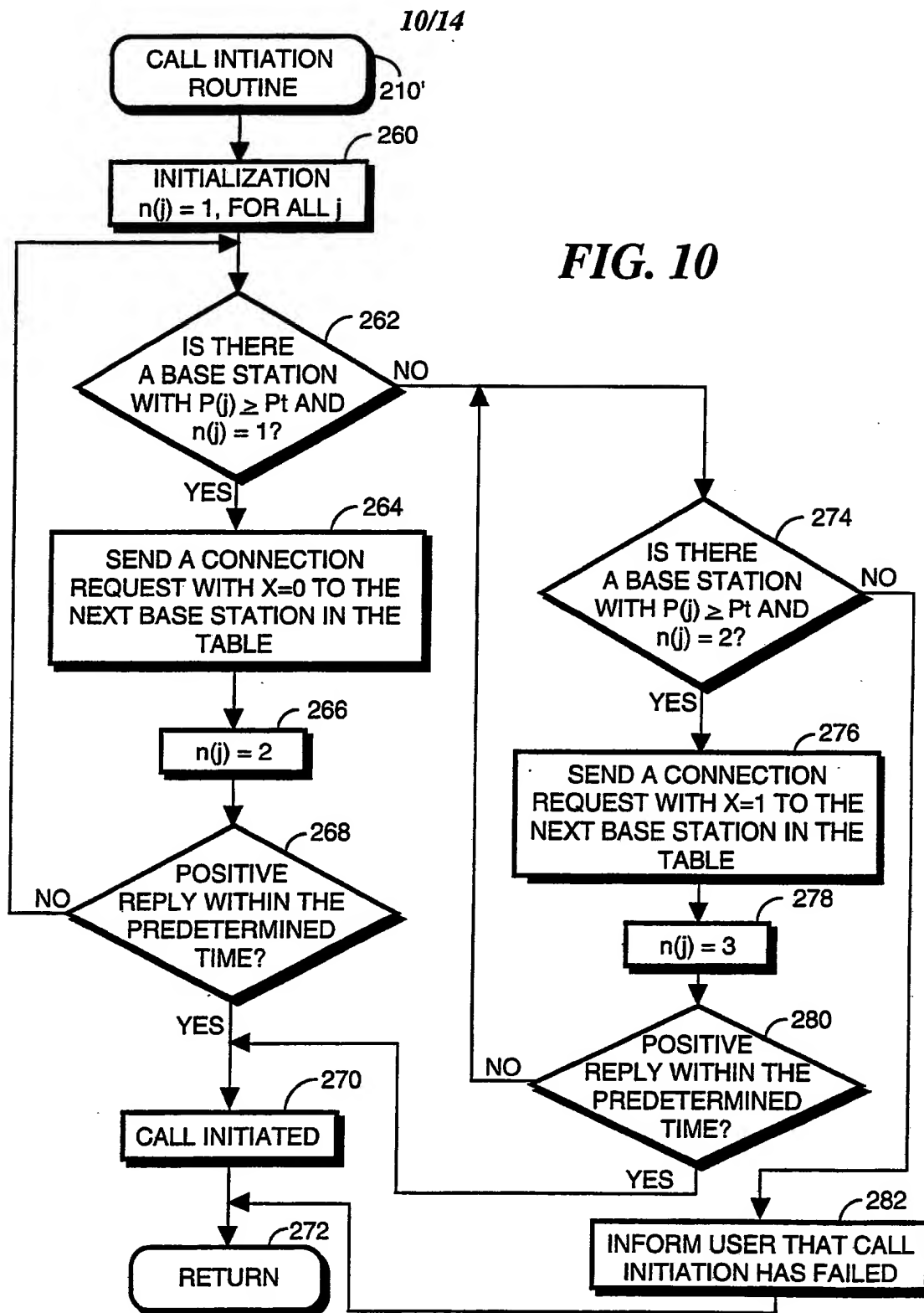


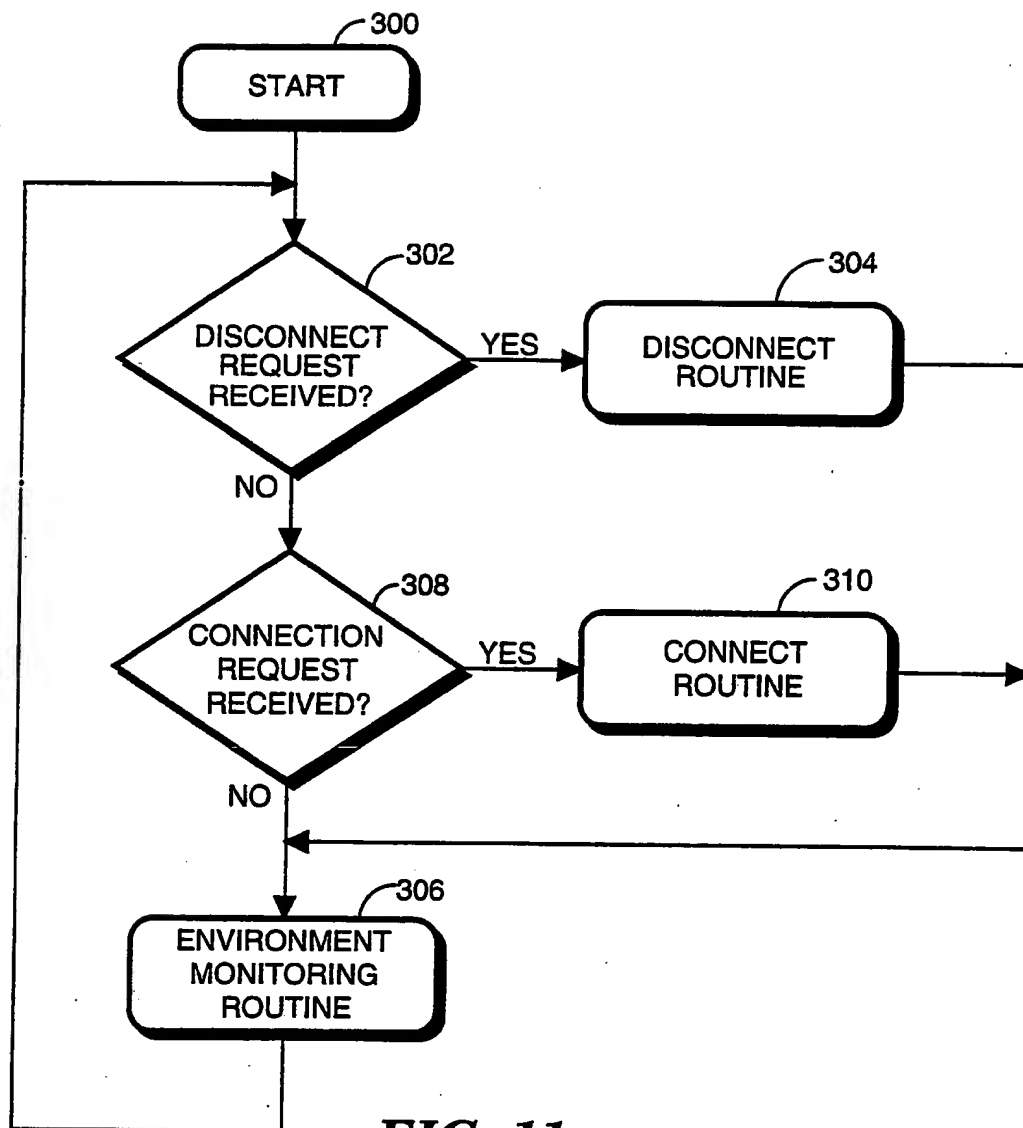
FIG. 9

FIG. 10



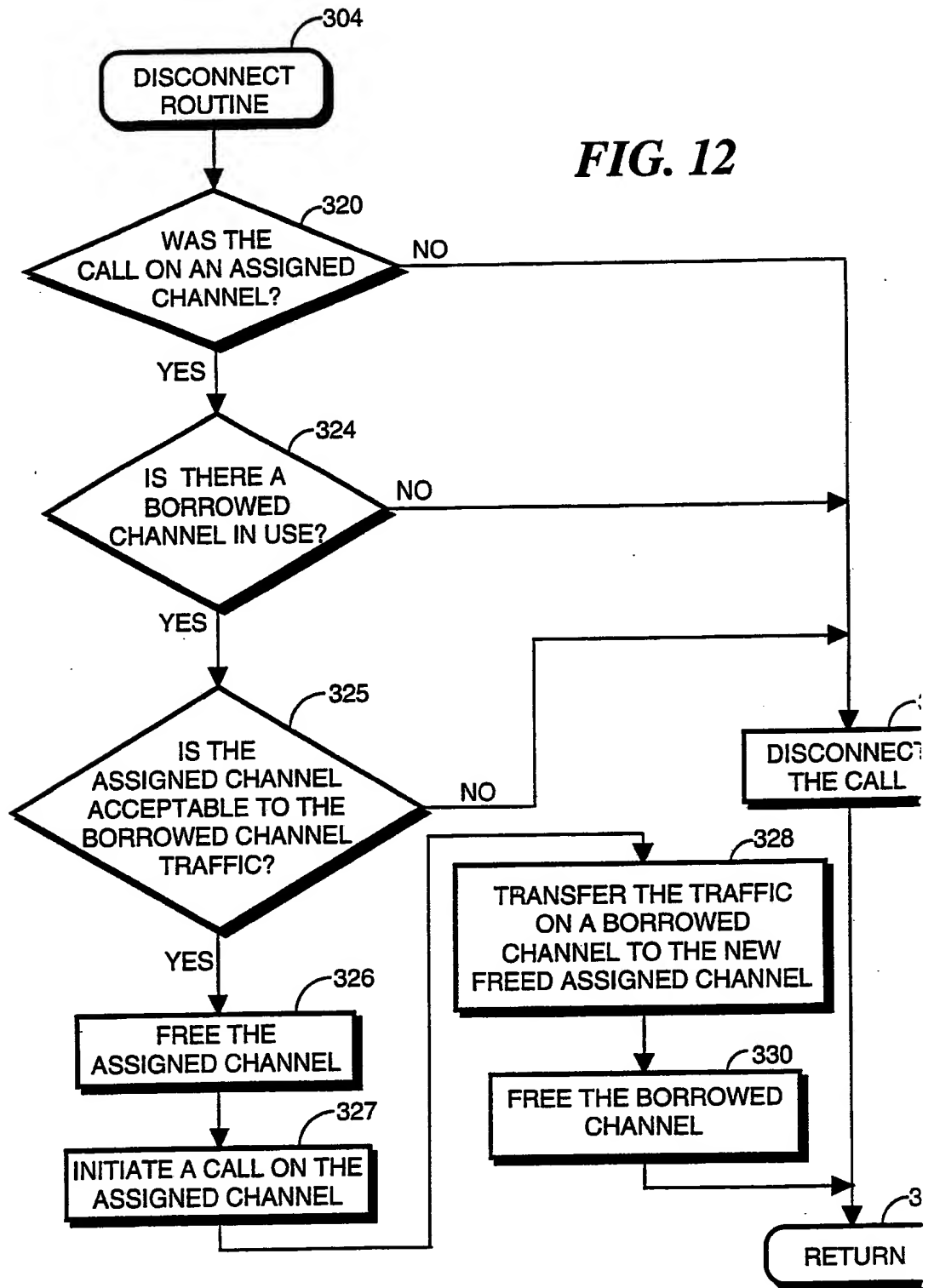


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**FIG. 11**

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FIG. 12



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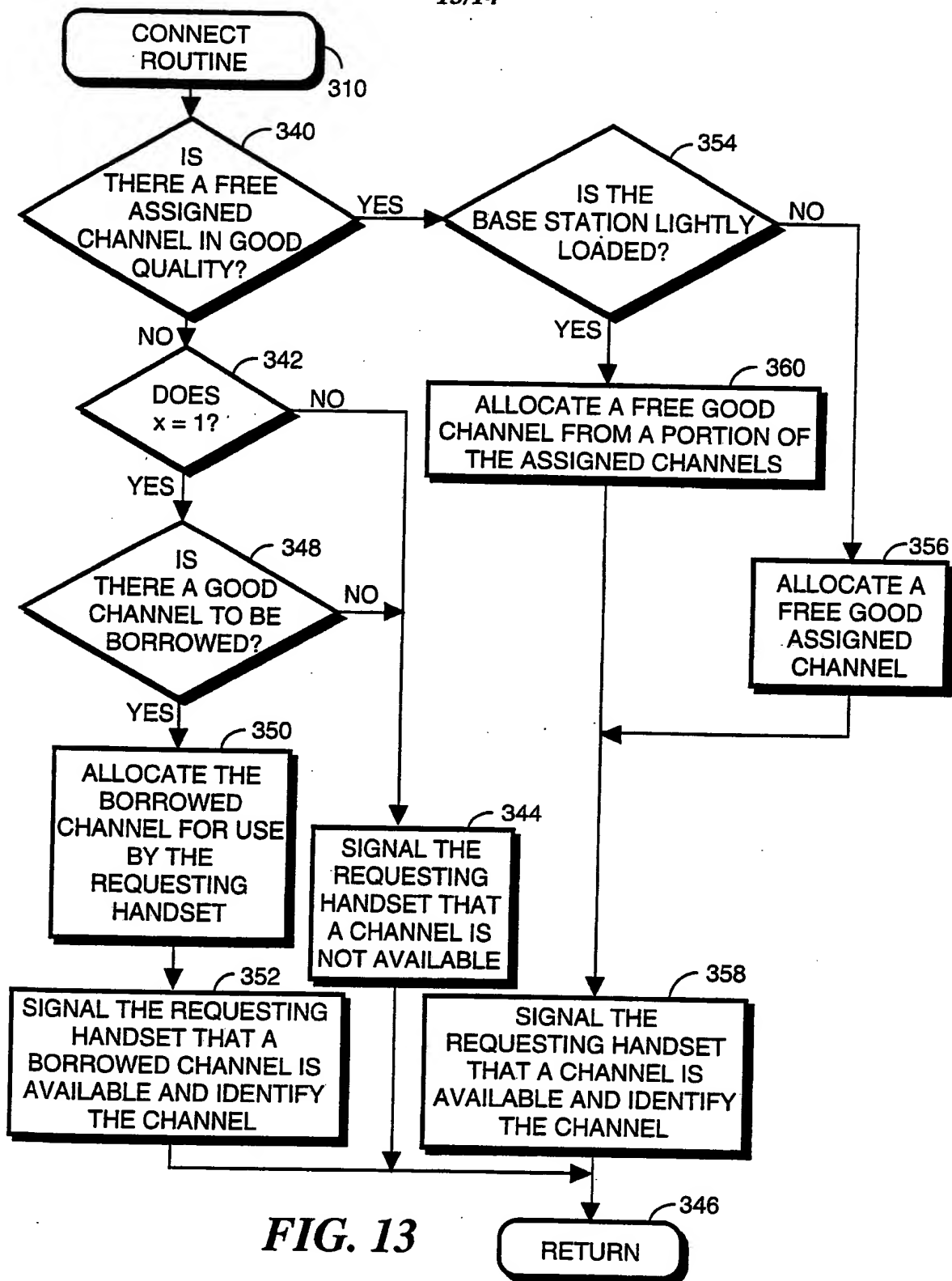
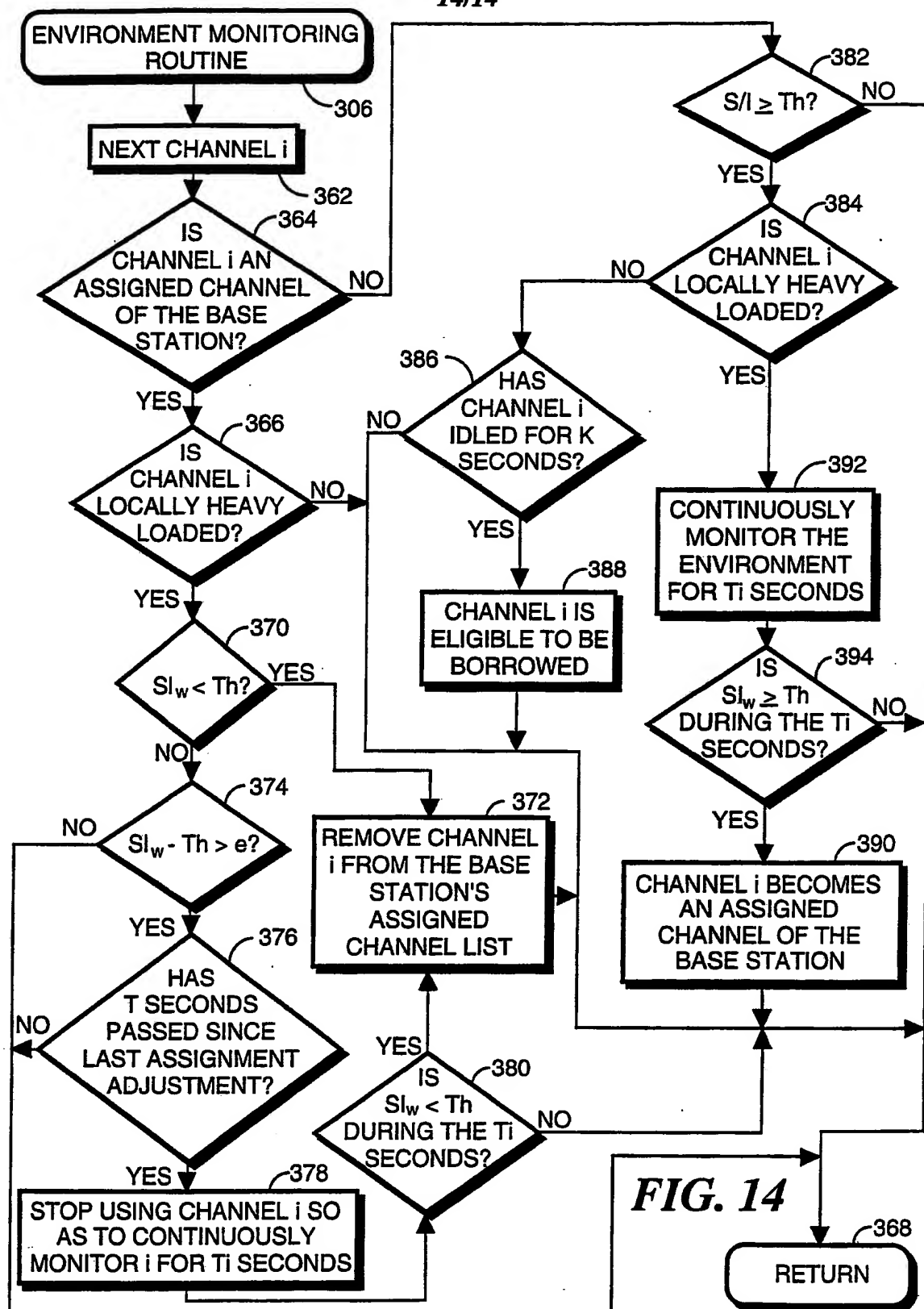


FIG. 13

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## INTERNATIONAL SEARCH REPORT

PCT/US92/10824

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(5) : H04B 15/00

US CL : 455/56.1, 62, 63, 379/58

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/33.1, 34.1, 34.2, 67.3; 379/59

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US,A, 5,093,927 (SHANLEY) 03 MARCH 1992 See figure 2.	1,13
X	US,A, 5,034,993 (SASUTA) 23 JULY 1991 See columns 2-3 and figure 2.	7-12 and 18-19
A,P	US,A, 5,148,548 (MECHE ET AL) 15 SEPTEMBER 1992 See entire document	1-23
A	US,E, RE 28,577 (SCHMIDT) 21 OCTOBER 1975 See abstract	1-23



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Date of the actual completion of the international search

03 FEBRUARY 1993

Date of mailing of the international search report

08 MAR 1993

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US92/10824

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A, 5,044,010 (FRENKIEL) 27 AUGUST 1991 See figure 2.	1-23
A,P	US,A, 5,093,924 (TOSHIYUKI ET AL) 03 MARCH 1992 See abstract and figure 5.	1-23

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